













Memoirs of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. XXXIV. No. 2.

---

HAWAIIAN AND OTHER PACIFIC ECHINI.

THE SALENIDÆ, ARBACIADÆ, ASPIDODIADEMATIDÆ,  
AND DIADEMATIDÆ.

BY

ALEXANDER AGASSIZ AND HUBERT LYMAN CLARK.

WITH SEVENTEEN PLATES.

PLATES 43-59.

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CAMBRIDGE, U. S. A. :

Printed for the Museum.

SEPTEMBER, 1908.





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\* Hawaiian species.

# HAWAIIAN AND OTHER PACIFIC ECHINI.

COLLECTED BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," COMMANDER  
CHAUNCEY THOMAS, U. S. N., COMMANDING IN 1902, AND LIEUT. COM-  
MANDER L. M. GARRETT, U. S. N., COMMANDING IN 1906.

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## SALENIDÆ Agassiz.

### THE PEDICELLARÆ AND OTHER STRUCTURAL CHARACTERS.

Plates 43, figs. 3-6 ; 45, and 46, figs. 1-8.

PEDICELLARÆ are usually common in the recent Salenidæ, especially abactinally and on the ambulacra. They are of two quite distinct types, each of which occurs in two forms. One type corresponds to the tridentate pedicellariæ of other Echini, but may have either three or four valves; the latter we may call "quadridentate." The other type corresponds to the ophicephalous pedicellariæ of other Echini, but may be either short-stalked with nearly spherical heads and so may be called "globose" pedicellariæ, or they may be long-stalked with more elongated heads and so may be called "ovoid" pedicellariæ. The stalk (Pl. 45, fig. 24) in all the pedicellariæ is made up of a dense, nearly solid calcareous network, and is not narrowed or peculiarly modified in any way at the top.

Although Döderlein (1906) has described and given some excellent figures of the pedicellariæ of *Salenocidaris profundis*, *S. varispina*, and *Salenia phoinissa*, we have felt that it was desirable to include those species in our discussion of the family, and to give some additional figures.

The *tridentate* pedicellariæ (Pl. 45, fig. 3) are fairly common in some species but are rare or entirely wanting in others. When present, they occur on the interambulacra, and mostly near the ambitus. The head is about as long as the stalk, and is attached to it by a short neck. The valves (Pls. 45, figs. 10, 11, 16, 17 ; 46, fig. 3) are from half to three-fourths of a millimeter long, and may be either curved or straight. As the diversities of form which they exhibit are fairly constant, they afford useful specific characters.

The *quadridentate* pedicellariæ (Pl. 45, fig. 1) are much less common than the tridentate, and are only known to occur in three species. They are usually found on the actinal part of the interambulacra. The head is shorter than the stalk, sometimes very much so, and there is practically no neck. The valves (Pls. 45, fig. 2; 46, figs. 1, 2) range from about three-fourths of a millimeter up to two millimeters in length and are straight and commonly more or less flat. They may afford useful specific characters. Döderlein found one of these pedicellariæ with *five* valves, but we have never seen more than four.

The *ovoid* pedicellariæ (Pl. 45, fig. 4) are not very common, but are usually to be found on the interambulacra. The head (Pl. 45, fig. 18) is about one-fourth of a millimeter long, and is attached to the stalk by a neck of about the same length. The stalk itself is three to six times as long as the head. The three valves (Pls. 45, figs. 5, 12, 23; 46, figs. 5, 6) are all alike and are distinctly longer than broad. They commonly lack an "articular loop" on the base, but this is occasionally present. For this reason, they seem to us to be modified ophicephalous pedicellariæ, while Döderlein considers them to be small tridentate. They are undoubtedly comparable to the triphyllous pedicellariæ of other Echini, but are hardly sufficiently modified to be called by that name.

The *globose* pedicellariæ (Pl. 45, fig. 6) are usually common and often abundant, and are to be found on all parts of the test, though they are most frequent on the ambulacra and about the abactinal system. There are often five groups of them present on the buccal plates in large specimens. The head is about one-fourth of a millimeter in length, and the stalk is usually about the same, though it may be twice as much; there is no neck. The valves (Pls. 45, figs. 7, 13, 19, 22; 46, fig. 4) are provided with an "articular loop" on the base, but as this is never very large, those of the same head do not differ appreciably from each other. The valves are short and deep, rounded at the tip, and about as wide as long. While there are usually only three, pedicellariæ with four such valves are occasionally to be found. In spite of the small size of the articular loop, there is no reason to doubt that these globose pedicellariæ of the Salenidæ are ophicephalous.

The sphæridia of the Salenidæ (Pls. 45, figs. 8, 14, 15, 25; 46, fig. 8; see also A. Agassiz's Panamic Deep Sea Echini, Pl. 19, fig. 2) occur on each ambulacrum, at or near the peristome. There are usually two, sometimes three or even more, rather close together, at the middle of the ambulacrum,



between the two columns of large tubercles. They are attached, in a more or less pendant condition, by very short stalks, to minute tubercles on the surface of the test. They are spheroidal in *Salenia*, but are usually ovoid or ellipsoidal in *Salenocidaris*. In all the recent species the sphæridia are attached flush with the test and not in any depression or concavity, but in the Upper Cretaceous *Goniophorus*, what are apparently deep pits for the sphæridia, like those of *Cœlopleurus*, are present in the actinal part of the ambulacra.

The calcareous particles or spicules of the Salenidæ (Pls. 45, figs. 9, 20; 46, fig. 7) are curved rods and perforated plates with more or less numerous and conspicuous projections. They exhibit great diversity, both in abundance and in size and degree of development. In their simplest form the curved rods have projections only on the convex side, but later (or in more developed examples) the projections are found on both sides. As these projections increase in length and thickness, they anastomose more or less freely, and very irregular, perforated plates are thus built up. The simplest rods occur in the pedicels, especially near the tips of the abactinal ones, while the most fully formed plates are found in the buccal membrane. Apparently the abundance and complexity of the calcareous particles increase with age. The slight differences noted between the species do not seem to be sufficiently tangible or constant to warrant their use as a specific character.

The general arrangement of the internal organs of the Salenidæ is shown in figs. 3-6, Pl. 43. The reproductive organs consist of short, dense tufts of tubules, apparently confined to the abactinal part of the test and body-cavity. The œsophagus is short and nearly straight. The stomach-intestine is only of moderate length, but shows the usual undulations. Its arrangement, however, is quite different in *Salenocidaris* from what it is in *Salenia*, as shown by the examination of a number of specimens of each genus. In *Salenia* (figs. 3, 4), the lower or actinal half of the stomach-intestine is distinctly undulated, raised in the ambulacra, lowered in the interambulacra, while the upper or abactinal half is much longer and narrower, and is nearly cylindrical; it is also greatly undulated, the interambulacral loops being particularly well marked. In *Salenocidaris* (figs. 5, 6), on the other hand, the undulations of the actinal half of the canal are scarcely visible, while the abactinal half is much shorter and stouter than in *Salenia*, with only the undulations of the posterior interambulacra marked, and at least two of these modified into small pouches.

## THE GENERA AND SPECIES OF SALENIDÆ.

This well-marked family contains ten apparently valid and clearly recognizable genera, of which, however, only two contain recent species. These genera are distinguished from each other by the position of the suranal plate, the condition of the tubercles (i. e. whether perforate or not), the presence or absence of compound ambulacral plates abactinally, the presence or absence of sphaeridial pits, and the ornamentation of the abactinal system. A convenient grouping of the genera according to these characters may be made as follows:

- Suranal plate axial and anterior, in contact with only four genital plates.
  - Primary interambulacral tubercles perforate.
    - Ambulacra broad, straight, or little flexuous, with perforate primary tubercles.
      - Ambulacral plates above ambitus, compound.
        - Compound ambulacral plates made up of 3 plates . . . *Acrosalenia*.
        - Compound ambulacral plates made up of 2 plates . . . *Plesiosalenia*.
      - Ambulacral plates above ambitus simple primaries . . . *Perisalenia*.
    - Ambulacra narrow, flexuous, with only imperforate small tubercles or granules . . . *Pseudosalenia*.
  - Primary interambulacral tubercles, imperforate.
    - Large pits (for sphaeridia?) present in actinal, ambulacral plates . *Goniophorus*.
    - No such pits present . . . *Peltastes*.
- Suranal plate not axial, but in contact with all five genital plates.
  - Primary interambulacral tubercles perforate . . . *Heterosalenia*.
  - Primary interambulacral tubercles imperforate.
    - Ambulacral plates compound, made up of 2 plates . . . *Salenia*.
    - Ambulacral plates, except one or two at peristome, simple primaries only.
      - Ambulacral tubercles numerous (more than 20); abactinal system with plates distinctly separated by grooves or pits and not covered with tubercles . . . *Salenidia*.
      - Ambulacral tubercles usually less than 15, rarely more than 20; abactinal system with plates not distinctly separated and covered with small, rough tubercles . . . *Salenocidaris*.

The genera *Hyposalenia* Desor and *Poropeltaris* (or *Poropeltis*) Quenstedt (1875, Petr. Deutsch.: Ech. p. 242) are simply synonyms of *Peltastes*, while *Trisalenia* Lambert appears to have been based on a misconception, and *Eosalenia* Savin is not one of the *Salenidæ*. Pomel's genera *Bathysalenia* and *Pleurosalenia* are not distinguishable from *Salenidia* and *Salenocidaris*.



## ACROSALENIA.

Agassiz, 1840. Ech. foss. Suisses, Pt. 2, p. 38.

Type-species, *Acrosalenia spinosa* Agass., 1840. Ech. foss. Suisses, Pt. 2, p. 39.

Jurassic and Lower Cretaceous Salenidæ.

## PLESIOSALENIA.

Valette, 1906. Bull. Soc. Sci. Hist. Nat. Yonne, LIX, p. 275.

Type-species, *Acrosalenia pentagona* Cott., 1879. Pal. Franç., Terr. Jur., p. 365.

Jurassic Salenidæ.

## PERISALENIA.

Valette, 1906. Bull. Soc. Sci. Hist. Nat. Yonne, LIX, p. 276.

Type-species, *Acrosalenia Gauthieri* Cott., 1879. Pal. Franç., Terr. Jur., p. 357.

Jurassic Salenidæ.

## PSEUDOSALENIA.

Cotteau, 1859. Rev. Mag. Zool., No. 4, p. 22.

Type-species, *Pseudosalenia flexuosa* Cott., 1859. Rev. Mag. Zool., No. 4, p. 24.

Jurassic Salenidæ.

## GONIOPHORUS.

Agassiz, 1838. Mon. d'Ech. Viv. et Foss., I, p. 30.

Type-species, *Goniophorus lunulatus* Agass., 1838. Mon. d'Ech. Viv. et Foss., I, p. 30.

Upper Cretaceous Salenidæ.

## PELTASTES.

Agassiz, 1838. Mon. d'Ech. Viv. et Foss., I, p. 27.

Type-species, *Peltastes pulchellus* Agass., 1838. Mon. d'Ech. Viv. et Foss., I, p. 27.

Upper Jurassic and Cretaceous Salenidæ.

## HETEROSALENIA.

Cotteau, 1861. Pal. Franç., Terr. Crét., p. 96.

Type-species, *Heterosalenia Martini* Cott., 1861. Pal. Franç., Terr. Crét., p. 97.

Cretaceous Salenidæ.

## SALENIA.

Gray, 1835. Proc. Zool. Soc. London, p. 58.

Type-species, *Cidarites scutiger* Goldfuss, 1829. Petrefacta, Pt. 1, p. 121.

Cretaceous, Tertiary, and Recent Salenidæ.

Three recent species of this genus are now to be recognized: *S. Pattersoni* A. Ag., which occurs from Western Cuba and Yucatan to Barbados, in 50–315 fathoms; the form collected by the “Valdivia” on Agulhas Bank, off

the Cape of Good Hope, in 56 fathoms, and identified by Döderlein as *Pattersoni*, but which is undoubtedly distinct from that species, and may be appropriately called *phoinissa* (=dark red); and *S. cineta* A. Ag. and Cl., collected by the "Albatross" in the northwestern Pacific, in 95-152 fathoms. (So far as can be judged from de Meijere's brief description, the small *Salenia* collected by the "Siboga" in the Sulu Archipelago, in 290 fathoms, and referred by him to *Pattersoni*, is probably *cineta*.) These three living species are all notable for their handsome coloration, the abactinal system being prettily ornamented, and the primary spines conspicuously banded or spotted with some shade of red. They may be distinguished from each other as follows:

- Actinal system, .40-.55 h. d.<sup>1</sup>; primaries rather slender, thickness commonly much less than 5 per cent of length; no red-brown pigment on test or secondaries.
- Abactinal system, .60-.70 h. d., light colored with plates outlined in deep violet; primaries with 3-5 broad bands of bright red . . . . . *Pattersoni*.
- \* Abactinal system, .55-.60 h. d., deep purplish; primaries with 12-16 narrow bands of dull red . . . . . *cineta*.
- Actinal system, .30-.35 h. d.; primaries rather stout, thickness often 4-5 per cent of length; test and secondaries with red-brown pigment; abactinal system about .55 h. d., very dark; primaries with 9 broad, brown-red spots on upper surface . . . . . *phoinissa*.

In addition to these differences, it is interesting to note that *Pattersoni* has both tridentate and quadridentate pedicellariæ, the latter with valves up to 2 mm. long, while *phoinissa* apparently lacks quadridentate, and the valves of the tridentate are seldom half a millimeter in length. In *cineta* neither tridentate nor quadridentate pedicellariæ have been found, and it would seem that they are characteristically absent. In Döderlein's description of the "Valdivia" specimen, he says there are 3 rows of secondary tubercles in the ambulacra. It is impossible to tell from the illustrations given whether this is really the case, or whether the "3" is not a misprint for 2. If it is not a misprint, we have here another very important difference between *phoinissa* and *Pattersoni*, for even the largest specimens of the latter have only 2 series of ambulacral tubercles.

<sup>1</sup> There are two abbreviations used frequently in the following pages, h. d. and v. d.; the former refers to the horizontal, the latter to the vertical diameter of the test.

**Salenia Pattersoni** A. Ag.

**Salenia Pattersoni** A. Agassiz, 1878. Bull. M. C. Z., V, p. 187.

Plates 43, figs. 3, 4; 46, figs. 1-8.

This species was not taken by the "Albatross," but is included in order to describe its pedicellariæ.

The distribution of the pedicellariæ is not peculiar, except that the abactinal system is strikingly free from them, save around the ocular plates; a few are also scattered among the anal plates.

The quadridentate pedicellariæ are very large, the head alone measuring up to as much as 2 mm. in length; the valves (Pl. 46, figs. 1 and 2) are straight, broad, and usually flat, but may be more or less compressed and hollowed out.

The tridentate are much smaller, the valves (Pl. 46, fig. 3) only .50-.75 mm. in length.

The ovoid pedicellariæ show some diversity in size and form; the valves (Pl. 46, fig. 6) are sometimes over .30 mm. long, and occasionally are distinctly pointed and provided with an "articular loop" (Pl. 46, fig. 5).

The globose pedicellariæ have the valves (Pl. 46, fig. 4) somewhat elongated, .16-.30 mm. in length.

**Salenia cincta** A. Ag. and Cl.

**Salenia cincta** A. Agassiz and Clark, 1907. Bull. M. C. Z., LI, p. 116.

Plates 45, figs. 22-25; 52, figs. 8-13; 57, figs. 1-3.

This handsome species is closely related to *S. Pattersoni* A. Ag., but is easily distinguished by its coloration. The test, secondary spines, and especially the abactinal system are a deep purple, or greenish more or less tinged with purple (Pl. 57, figs. 1-3). The primary interambulacral radioles are white, more or less tinged with green on the upper side, with 12 to 16 broad rings of dull brick-red. The longest radiole of the specimen figured (Pl. 57, fig. 1) is 52 mm., with sixteen bands.

The ambulacral miliary spines are stout, flat, rectangular, with rounded outer angles about 1.75 mm. long, in marked contrast to the thin ones of *S. Pattersoni*. The test is much flatter than that of *Pattersoni*; a specimen (Pl. 52, figs. 8, 9) 12 mm. in diameter is 7 mm. in height, while a

specimen of *Pattersoni* 11.5 mm. in diameter is more globular, being 9 mm. in height. The proportions of the actinal and abactinal systems are nearly the same; in *S. cincta* the abactinal system is 7 mm. in greatest diameter, the actinal, 5.7 mm; in *S. Pattersoni* they are 7.5 mm. and 5.6 mm. The interambulacral system is composed of six or seven primary plates in each column. The primary tubercles are comparatively small, the median edge of the plates being occupied by rather large secondary tubercles (Pl. 52, fig. 11) set closely together and forming two vertical lines, with a deeply sunken and narrow groove between them, giving the interambulacral face of the test much the appearance of having a sunken groove as in *Goniocidaris canaliculata*. This feature is scarcely shown in Pl. 52, figs. 8 and 11, as the drawing is not shaded. On the edge of the plate adjoining the ambulacral system there are only two secondary tubercles, one in each angle of the coronal plate (Pl. 52, fig. 11).

In the ambulacral system there are either 14 or 15 plates of nearly uniform size in each column. Each plate carries a primary tubercle and, except the uppermost and lowermost, one or two secondaries. These plates are made up of two components which are abactinally of nearly equal size but actinally appear more clearly as a primary plate and an accessory plate. The *Hemicidaris* character of the actinal ambulacral tubercles is but slightly developed (Pl. 52, figs. 8, 10).

The actinal system is covered by six more or less concentric series of irregularly pentagonal or hexagonal plates, the pairs of poriferous plates forming the most prominent series; these pairs are separated from each other by a set of narrow intercalated plates connecting the actinal with the outer rows.

The abactinal system is very striking from the prominent horseshoe-shaped ridge which borders the ocular plates (Pl. 52, fig. 9) and the regular heptagonal outline of the lateral genital plates. The suranal plate, the odd genital, the right posterior ocular and the right posterior genital plates surround the anal system. This is covered with small irregularly arranged pentagonal or polygonal plates, the larger plates carrying a single minute miliary. The ocular plates are of uniform size, with the exception of the right posterior ocular, which is somewhat smaller. The genital ring and the suranal plate are covered with a fine granulation; a small heart-shaped shield covers the surface of the oculars, which appear like triangular plates with convex pointed sides cutting into the genital ring, but owing

to their nearly straight outer sides they scarcely project beyond the general line of the genital ring.

The tridentate and quadridentate pedicellariæ are entirely wanting in all the specimens examined. The ovoid pedicellariæ are very small, the valves (Pl. 45, fig. 23) less than .20 mm. long and the stalk little longer; they are very scarce, and appear to be confined to the vicinity of the actinostome. The globose pedicellariæ are also very small, the valves (Pl. 45, fig. 22) measuring only .15-.25 mm., but the stalk is in proportion noticeably long, .25-.50 mm. They are rather infrequent, occurring only near the ocular plates, along the ambulacra and on the actinostomal plates.

This species was collected at the following stations:

Station 4893. Southwest of Goto Islands, Japan. Bott. temp. 55.9°. 95-106 fathoms. Gy. s. br. sh. p.

Station 4894. Southwest of Goto Islands, Japan. Bott. temp. 55.9°? 95 fathoms. Gy. s. br. sh. p.

Station 4895. Southwest of Goto Islands, Japan. Bott. temp. 55.9°? 95 fathoms. Gy. s. br. sh. p.

Station 4934. Off Kagoshima Gulf, Japan. Bott. temp. 56°? 103-152 fathoms. Rky.

Station 4936. Off Kagoshima Gulf, Japan. Bott. temp. 60.6°? 103 fathoms. St.

Bathymetrical range, 95-152 fathoms. Extremes of temperature, 60.6°?-55.9°. Twelve specimens.

#### SALENIDIA.

Pomel, 1883. Class. Meth., p. 94.

Type-species, *Salenia gibba* Agass. 1838. Mon. d'Ech. Viv. et Foss., I, p. 13.

Upper Cretaceous and Tertiary Salenidæ.

#### SALENOCIDARIS.

A. Agassiz, 1869. Bull. M. C. Z., I, p. 254.

Type-species, *Salenocidaris varispina* A. Ag., 1869. Bull. M. C. Z., I, p. 254.

Recent Salenidæ.

Four valid species of this genus may now be recognized, although they are very closely related, and young specimens are very difficult to identify. In the order of their discovery these species are as follows: *S. varispina*



A. Ag., which occurs in the Western Atlantic Ocean and Caribbean Sea, at depths of 150–950 fathoms, though most commonly below 400; *S. profundus* Duncan (commonly known as *S. hastigera* A. Ag., but as the two names refer to the same species, the earlier must have precedence), which is apparently almost cosmopolitan, having been reported from the north and south Atlantic and from a number of stations in the East Indian region, at depths of 100–1850 fathoms, though most commonly below 1000; *S. miliaris* A. Ag., which is known from various stations in the north Pacific, between the Gulf of Panama and Japan, at depths of 670–1680 fathoms; *S. crassispina* A. Ag. and Cl., which is known only from a single Hawaiian specimen, taken in 147–198 fathoms. There can be no doubt that *goesiana* Lovén is based on a very young specimen of either *varispina* or *profundus*, one cannot say which. The species figured by Wyville Thomson in “The Voyage of the Challenger: The Atlantic” (Vol. I, figs. 31, 32), as *varispina* is a young *profundus*. The specimens given by de Meijere (1904) and Döderlein (1906) as *hastigera* are probably *miliaris*, but as those writers neither describe nor figure the relation of the ocular plates to the anal system, the point cannot be positively determined; the large number of ambulacral plates and the great height of the test in Döderlein’s specimen indicate *miliaris*. Döderlein now (1906) considers his Japanese species, *pacifica*, as identical with *hastigera*, but it seems more probable that it is *miliaris*; this is certainly indicated by the abactinal system (compare A. Agassiz, 1881, Challenger Echini, Pl. 4, fig. 10; Döderlein, 1887, Jap. Seigel, Pl. 11, fig. 9; and A. Agassiz, 1904, Panamic Deep Sea Echini, Pl. 16, fig. 4). The species of this genus have pure white primary spines, while the test, secondaries, and abactinal system are more or less deeply colored with violet or purple pigment. They may be distinguished from each other, when adult, by the following characters, but it must be borne in mind that specimens under 9 mm. h. d. are young and cannot be distinguished in all cases with certainty.

Primary spines, long and slender, with numerous whorls of minute, delicate teeth; greatest thickness of shaft rarely equalling, and usually much less than, diameter of milled ring.

Coronal plates 8 or 9 (often 7 in specimens less than 9 mm. in diameter); each of the two series of ambulacral tubercles consists of 5 (3–6) larger tubercles actinally and 8 (7–10) smaller ones abactinally; size small, h. d. seldom exceeding 10 mm.; v. d., .40–.50 h. d., or, including the abactinal system, .50–.70 h. d., but usually less than .60; abactinal system usually less than .60 h. d.; actinal system usually less than .50 h. d. . . . . *varispina*.

- Coronal plates 6 or 7 (rarely 8 in specimens over 15 mm. h. d.); each of the two series of ambulacral tubercles consists of 3 (2-4) larger tubercles actinally and 11 or more (8-19) abruptly smaller ones abactinally; size larger, h. d. sometimes exceeding 16 mm.
- V. d., .50-.55 h. d., or, including the abactinal system, .60-.80 h. d., but usually about .70; abactinal system, .65-.75 h. d.; actinal system, .50-.60 h. d.; abactinal system, *even in mature specimens*, with right posterior ocular plate excluded from the periproct; ambulacral plates 10-15 in each column . . . . . *profundi*.
- V. d., .60-.70 h. d., or, including the abactinal system, .75-.90 h. d., but usually about .80; abactinal system, .60-.70 h. d.; actinal system about .50 h. d.; abactinal system with right posterior ocular plate usually in contact with the periproct; ambulacral plates 14-22 in each column . . . . . *miliaris*.
- Primary spines shorter and much stouter, verticillate but quite smooth; greatest thickness of shaft equalling or exceeding diameter of milled ring . . . . . *crassispina*.

### **Salenocidaris varispina** A. Ag.

**Salenocidaris varispina** A. Agassiz, 1869. Bull. M. C. Z., I, p. 254.

Plate 45, figs. 10-15.

This species was not taken by the "Albatross," but is included so as to give an account of the pedicellariæ.

The distribution of the pedicellariæ is practically the same as in the other Salenidæ, but they seem to be less abundant. The abactinal system carries very few as compared with that of *miliaris*.

The quadridentate seem to be entirely wanting, but the tridentate are not rare and are very characteristic. The valves (figs. 10, 11) are .50-.60 mm. in length, strongly curved and indented near the tip. The ovoid pedicellariæ are very scarce, and have valves (fig. 12) only .15-.25 mm. long. The globose show little variety in appearance; the valves (fig. 13) range from .12-.30 mm. in length and are decidedly longer than broad.

**Salenocidaris profundus** A. Ag. and Cl.

*Salenia profundus* Duncan, 1877. Ann. Mag. Nat. Hist. (4), XX, p. 70.

*Salenia hastigera* A. Agassiz, 1879. Proc. Am. Acad., XIV, p. 198; 1881, Challenger Echini, p. 54, Pl. 4, figs. 3-17.

Plate 45, figs. 16-21.

This species was not taken by the "Albatross," but is included so as to give an account of the pedicellariæ.

The distribution of the pedicellariæ is much as in the other species of the genus, but the globose are very abundant, particularly on the abactinal system. The quadridentate and tridentate are infrequent or rare, and almost wholly on the actinal side. Their valves (figs. 16, 17) are long, narrow, and nearly straight, and thus quite different from those of *varispina*. The ovoid pedicellariæ (fig. 18) are not peculiar, but the globose are commonly distinguishable from those of *varispina* by the valves (fig. 19) being nearly as wide as they are long.

**Salenocidaris miliaris** A. Ag. and Cl.

*Salenia miliaris* A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 74.

Plates 43, figs. 5, 6; 45, figs. 1-8.

The quadridentate pedicellariæ (Pl. 45, fig. 1) are rather infrequent, and occur only actinally and usually on the interambulacra. The stalk is shorter than the valves (Pl. 45, fig. 2), which are from .75-.95 mm. long.

The tridentate pedicellariæ (Pl. 45, fig. 3) occur also on the interambulacra, but only near the ambitus, and are not very common. The stalk is about equal to the valves, which are .60-.80 mm. in length.

The ovoid pedicellariæ (Pl. 45, fig. 4) are quite infrequent, and are found chiefly on the interambulacra. The stalk nearly equals the head in thickness, and is five or six times as long; the valves (Pl. 45, fig. 5) measure about .20-.25 mm. in length.

The globose pedicellariæ (Pl. 45, fig. 6) are very abundant all over the abactinal system and on the ambulacra; they are less common on the interambulacra; on the actinostomal membrane there are five small, radial clusters of them. The valves (Pl. 45, fig. 7) nearly equal the stalk in length, measuring .12-.30 mm.



This species was taken by the "Albatross" at the following stations:

Station 4060. Off Alia Point Light, N. E. coast of Hawaii, Hawaiian Islands. Bott. temp. 36.5°. 759-913 fathoms. Fnc. gy. vol. s. for. r.

Station 4125. Off Kahuku Point, Oahu, H. I. Bott. temp. 36.4°. 963-1124 fathoms. Br. m. for. r.

Station 4181. Off Hanamaulu, Kauai, H. I. Bott. temp. 38.1°. 671-811 fathoms. Mang. s. glob.

Station 5084. Off Omai Saki Light, Hondo, Japan. Bott. temp. 36.8°. 918 fathoms. Gn. m. fine. s. glob.

Bathymetrical range, 671-1124 fathoms. Extremes of temperature, 38.1°-36.4°. Six specimens.

**Salenocidaris crassispina** A. Ag. and Cl.

*Salenia crassispina* A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 234.

Plates 45, fig. 9; 52, figs. 1-7.

A single small specimen of this species (Pl. 52, figs. 1-2) was collected off the West coast of Hawaii in comparatively shallow water, 147-198 fathoms. It measures 4.8 mm. in diameter and 3 mm. in height, and the actinostome is 1.7 mm. in diameter. It is undoubtedly an immature specimen.

It has five-six or six-six interambulacral plates, with two large secondary tubercles at the median suture and one or two smaller tubercles at the line of junction (Pl. 52, fig. 4) between the ambulacral and interambulacral systems. Three or four of the primary interambulacral tubercles, with huge mammary bosses, are much larger than the others and carry remarkably stout radioles (Pl. 52, figs. 5-7), which, though distinctly distantly verticillate, yet are quite smooth (Pl. 52, fig. 6) save for a little serration near the slightly curved tip of the spine (Pl. 52, fig. 7).

The diameter of the radioles is frequently equal to, or even larger than, that of the milled ring, and the longest one is only 19 mm. There are nine-nine or nine-ten ambulacral plates, their tubercles occupying the whole median part of the plates. The ambulacral pores are on the lower angle of the plates, and on the upper plates can barely be distinguished (Pl. 52, fig. 3), the tubercles occupying nearly the whole of these upper plates. The Hemicidaris-like development of the actinal tubercles is very marked (Pl. 52, figs. 1, 3). The ambulacral miliaries are short. On the actinal side of the test there are a few short, pointed, flat serrated radioles.

The actinostome (Pl. 52, fig. 1) is covered with a pavement of three rows of comparatively large pentagonal or hexagonal plates, the row of poriferous plates being the largest.

The second actinal ambulacral plate in each column and rarely the third, are compound plates (Pl. 52, fig. 1).

The sculpture of the abactinal system consists of an irregular indefinite pattern (Pl. 52, fig. 2) which is most prominent on the left lateral genitals and the left anterior ocular. The anal system is wholly included by the suranal plate, the odd and the right posterior genital plates, the right posterior ocular not being in contact with the anal system. The genital plates are irregularly longitudinally heptagonal and form a continuous ring. The oculars are pentagonal widest in the angle of contact with the genital plates. The anal system is covered by eight triangular plates, four of which are larger than the others and carry indistinct miliaries.

Although the primary spines appear to be so characteristic, it is quite possible that more extensive material will prove this species to be based on an aberrant, young individual of *miliaris*.

So far as can be determined from the single, small specimen, the pedicellariæ do not differ from those of *miliaris*, but no quadridentate or tridentate pedicellariæ were found.

This species was taken by the "Albatross" only at

Station 4045. Off Kawaihae Light, W. coast of Hawaii, H. I. Bott. temp. 49°. 147-198 fathoms. Co. s. for. One specimen.

#### ARBACIADÆ Gray.

##### THE PEDICELLARIÆ AND OTHER STRUCTURAL CHARACTERS.

Plates 44, figs. 1, 2; 46, figs. 9-16; 47; 48; 49.

The pedicellariæ of the Arbaciadæ are of two quite distinct types, the tridentate and ophicephalous. Whether true triphyllous pedicellariæ also occur is a debatable question, but we have found it convenient to differentiate under that name certain small pedicellariæ, occurring in a number of species, in which the valves are relatively wider and more leaf-like than in even the smallest tridentate pedicellariæ of the same species. It may be frankly stated, however, that as these small pedicellariæ intergrade completely, in most cases, with the tridentate and in some species are not distinguishable at all, it would be equally correct to consider them simply as a form of the tridentate, and

this position would be strengthened by the fact that they are provided with a "neck" and the valves have an "articular loop," quite like those of the tridentate.

One of the most striking features of the family, so far as the pedicellariæ are concerned, is found in the structure of the stalk, which is always made up of a bundle of calcareous threads, parallel and unconnected, united only at the top and base, save for their organic covering. When treated with alkali, therefore, and this covering thereby removed, the threads easily separate from each other (Pls. 46, fig. 12; 47, fig. 4). The upper end of the stalk is always a dense mass of calcareous tissue of variable size and shape, and it is interesting to note that each species shows a fairly constant, characteristic form. The constancy is not so great, however, as to warrant the use of this feature for a specific character (compare Pls. 47, figs. 4, 13, and 18; 48, fig. 18).

The tridentate pedicellariæ (Pls. 46, fig. 9; 47, fig. 1) are seldom abundant, frequently common, often rare, and occasionally wholly wanting. If present, they occur at or below the ambitus, less commonly on the abactinal surface, and very rarely on genital or ocular plates. They show a very extraordinary range of size and form. They are always provided with three, and only three, valves, and these are attached to the stalk by a more or less elongated, muscular "neck." The upper end of the stalk is commonly enlarged and rounded (Pl. 49, fig. 25). The valves may be very narrow, (Pl. 49, fig. 23), and even compressed (Pl. 46, fig. 11), the greatest width less than one-third the length, or they may be very broad and flat (Pls. 48, fig. 15; 49, fig. 19), the width two-thirds the length. They range in length from .20 to 2.65 mm., while the stalk is equally variable, sometimes barely equalling the head, often 3-5, rarely 10-15, times as long. The blade usually contains a more or less considerable meshwork of calcareous matter, and often the apophysis is continued as a noticeable ridge, well toward the tip of the valve. Sometimes, however, there is no calcareous meshwork, and often the apophysis simply forks at the base of the blade. In one particular the tridentate pedicellariæ of this family are remarkable, and resemble the ophicephalous pedicellariæ, and that is in the presence of a distinct "articular loop" on the base of each valve. Unlike the ophicephalous pedicellariæ, however, the three valves do not show any noticeable individual diversity in any one pedicellaria, the articular loop being of practically the same size on each valve. Individual diversity among the tridentate pedicel-

lariæ is comparatively slight, except in the matter of size, and it seems possible to find good generic, and even specific, characters in the form of the valves. In view of the difficulty, if not impossibility, of doing this in the Cidaridæ, it may seem very improbable that it can be done in the Arbaciadæ; but a little consideration will make clear the difference between the two families. In the Cidaridæ, the spines, as well as all other outgrowths from the test, show a remarkable diversity of form even in a single species, and individual differences are very great; it is not strange, therefore, that little reliance can be placed on the pedicellariæ for purposes of classification. In the Arbaciadæ, on the other hand, the spines are remarkably constant in form in any given species, and it is not strange, therefore, that the pedicellariæ show a similar constancy. It is interesting to note further that the longest and slenderest tridentate pedicellariæ occur in that genus (*Cœlopleurus*) which has the longest and slenderest spines, while those genera (*Habrocidaris*, *Podocidaris*) which have short flattened spines have the valves of the tridentate pedicellariæ short and flat.

The ophicephalous pedicellariæ (Pl. 47, fig. 2) are almost invariably abundant, especially on the actinal surface, but their abundance shows considerable variability in different individuals. They are always to be found, and usually in numbers, on the buccal plates and on the ambulacral plates of the peristome, and the whole ambulacrum, even up to the ocular plate, is sometimes thickly covered with them. The heads vary in length from .20 to .75 mm., but there is comparatively little diversity in any one individual. The stalks, on the other hand, are exceedingly variable in length, ranging from three to twenty times the length of the head. The valves rest almost directly on the head of the stalk, no "neck" being present, and the upper end of the stalk is accordingly flattened or even concave. The exact form of this upper end is very variable, though fairly constant within specific limits. The valves are always provided with a conspicuous articular loop, and as this varies greatly in size on the three valves, we can readily distinguish between valves *a*, *b*, and *c* (Pl. 47, figs. 7-9). In *a* the loop is largest, in *c* it is smallest. In their natural position the loop of *b* overlies that of *c*, while that of *a* overlies both. The blade of the pedicellaria is not appreciably modified by this striking difference in the basal part. Although the apophysis always forks at the base of the blade, one branch merging into each margin, a portion of it often continues nearly to the tip as a more or less conspicuous ridge, which is usually accompanied by a group of coarse cal-



careous branches on each side. The shape of the blade differs greatly in the different genera, and even in different species.

The triphyllous pedicellariæ (Pl. 47, fig. 3) are always uncommon, often rare, and frequently wanting. When present, they are usually to be found on the abactinal surface near the boundaries of the interambulacra, and rarely on the genital plates. They are always small, provided with a long neck, and intergrade almost completely with the tridentate. The head is only .18-.40 mm. in length, but the stalk is commonly eight to ten times as long. The valves (Pl. 46, fig. 16) are provided with a small articular loop, but these do not overlap, and the three valves of a head are all alike. The apophysis does not continue into the blade, nor is any calcareous network developed there. No "cover plate," so evident in the triphyllous pedicellariæ of the Aspidodiadematidæ and Echinothuridæ, is ever present.

Sphæridia (Pls. 47, figs. 10, 15-17; 48, fig. 19; 49, figs. 1, 9, 15, 26) are present in the ambulacra of all the Arbaciadæ, at least at the peristome. They show considerable diversity in size (.20-.50 mm. in diameter) and form, and apparently vary more or less with the age of the individual (compare figs. 15 and 16, Pl. 47). No reliance can be placed on their form as a specific character. They may be nearly or quite globular, and occasionally they are longer than wide, but as a rule they are much wider than long. They are borne in an upright position on a very short stalk which is jointed to a small knob or projection of the test. They may be placed on the surface of the test with little or no concavity back of them (*Podocidaris*, *Dialithocidaris*, *Habrocidaris*), or they may be more or less deeply sunken in pits in the test (*Arbacia*, *Cœlopleurus*). In *Cœlopleurus* there are 6-12 sphæridia in each ambulacrum, arranged vertically, so that there is a pit at the inner angle of each of the lowermost ambulacral plates (Pl. 53, fig. 1). In all the other genera a single sphæridium is present in each ambulacrum close to the peristomal margin.

The pedicels of the actinal surface are always provided with the usual calcareous terminal rosette and its accompanying supporting plates (Pl. 48, figs. 7, 8), but on the abactinal surface of the test these are commonly wanting. In some species no other calcareous deposits appear to be present in the pedicels, but usually some sort of supporting rods are found (Pls. 48, figs. 9, 17, 21; 49, figs. 3, 11, 20, 27). These may be simple, rough, irregular, slightly curved, non-perforated rods (*Cœlopleurus*), or straight, smooth rods, expanded and perforated at the middle (*Podocidaris*, *Habrocidaris*,

some Arbacias), or narrow, curved perforated plates (*Dialithocidaris*), or more irregular, wider, rough perforated plates (*Arbacia stellifera*). It is doubtful how much reliance can be placed on these calcareous particles for specific characters.

The gills of the Arbaciadæ contain more or less numerous perforated plates (Pls. 47, figs. 11, 19; 49, fig. 28), which apparently increase in number and complexity with age. In their simplest condition they are smooth, flat plates with few, large perforations (Pl. 47, fig. 11), but they often have numerous knobs or projections on the surface and are perforated with many small holes. Sometimes they become still more complex, and are irregular masses of calcareous tissues (Pl. 47, fig. 19). When very large and well developed, they frequently carry pedicellariæ.

The general arrangement of the internal organs of the Arbaciadæ is shown in the figures given of *Cœlopleurus* (Pl. 44, figs. 1, 2). The reproductive organs form finely divided tufts in each interambulacrum, the size of which varies of course with the sexual condition of the specimen. The œsophagus is moderately long and connects abruptly with the remarkably large, flat, stomach-intestine, which is very slightly undulated. The upper intestine is more undulated and shows five distinct interradiæ "pockets." It ends in a short but wide rectum.

#### THE GENERA AND SPECIES OF ARBACIADÆ.

This easily recognized family contains seven apparently valid genera, all of which contain recent species. These genera are distinguished from each other by the primary spines, the thickness of the test, the number of anal plates, the structure of the ambulacral plates, the absence or presence and arrangement of non-articulated spines and of secondaries, and the pedicellariæ. A convenient grouping of the genera according to these characters may be made as follows:

Primary spines short, never much longer than diameter of test; spheroidal pits wanting or one present at peristome in each ambulacrum.

Test thick and solid as in most regular Echini; primary spines cylindrical or flattened; valves of tridentate pedicellariæ not remarkably flattened; valves of ophicephalous pedicellariæ not extraordinarily constricted nor with unusually expanded apophysis.

Abactinal surface with numerous articulated primary spines, which are more or less cylindrical, though they may be flattened near tip.

- Ambulacral plates at ambitus with 3 (exceptionally 4) pairs of pores; secondary spines and tubercles wholly wanting *Arbacia*.
- Ambulacral plates at ambitus with 4 or 5 pairs of pores; secondaries present in interambulacra at and above ambitus *Tetrapyrgus*.
- Abactinal surface with numerous short, non-articulated spines; primary spines flattened, with more or less serrate edges, confined to ambitus or actinal surface of test.
- Abactinal system small or of moderate size, not .60 h. d.; anal plates, 4.
- Abactinal system about .35 h. d.; non-articulated spines not arranged in horizontal series on each abactinal coronal plate; tridentate pedicellariæ small, with valves only about .30 mm. long . . . . . *Podocidaris*.
- Abactinal system about .50 h. d.; non-articulated spines arranged in horizontal series of 4-7 on each abactinal coronal plate; tridentate pedicellariæ very large, with compressed valves, 2-2.5 mm. long . . . *Dialithocidaris*.
- Abactinal system very large, about .66 h. d.; anal plates, 5 . . . *Pygmaeocidaris*.
- Test thin and delicate; anal plates, 5; primary spines decidedly triangular in cross-section; valves of tridentate pedicellariæ remarkably wide and flat; valves of ophicephalous pedicellariæ extraordinarily constricted, with notably expanded and hollowed apophysis . . . . . *Habrocidaris*.
- Primary spines very long and usually tapering, greatly exceeding twice diameter of test; sphaeridial pits 6-12 in each ambulacrum actinally . . . *Cæloplecurus*.

## ARBACIA.

Gray, 1835. Proc. Zool. Soc. London, p. 58.

Type-species, *Cidaris pustulosa* Leske, 1778. Add. Klein, p. 85.

Tertiary (?) and Recent Arbaciadæ.

There seem to be only five valid species of this genus, although Lovén, in his revision of it in 1887, recognized double that number. Lovén, however, considered as a good subgeneric character, one which we find cannot be relied on even to distinguish a given species, namely, the extent to which the abactinal interradiat areas are free from spines, and he recognized individual differences such as the form of the test as valid specific characters. We are entirely unable to find any character which will distinguish specimens from Brazil from those taken in the Mediterranean, while Lovén considered them as two quite distinct species. It is possible that further material from the west coast of Africa will make the recognition of the species *africana* Troschel desirable, and there is also a possibility that *alternans* Troschel may ultimately be separable from *Dufresnii* Bl., but in the light of such material as is now available either in the M. C. Z. or elsewhere, these three names

seem to be synonyms. The species which we recognize are *lixula* Linn. (including *pustulosa* Leske, *aquituberculata* Bl. and *australis* Trosch.), from the tropical Atlantic, ranging from the Mediterranean and Gulf of Guinea to Brazil; *Dufresnii* Bl. (including *africana* and *alternans* of Troschel), from southern South America, Tristan d'Acunha, and West Africa; *punctulata* Lamk., from the east coast of the United States and Mexico; *spatuligera* Val. (including *grandinosa* Val.), from Peru and Chili; and *stellata* Bl., from the west coast of Mexico and Central America. All of these species are distinctly littoral, rarely occurring in depths exceeding 100 fathoms.

In distinguishing the species of this genus, we find that no reliance can be placed on the extent to which the interambulacra are covered by the primary spines. Nor is this even an age character, for specimens of the same size, of *punctulata* from Woods Hole and Newport, reveal the most striking differences in this particular. The relation of the oculars to the periproct, the number of primary tubercles on each coronal plate at the ambitus, the sculpturing of the epistroma, and even, to some extent, the color and size, appear to furnish the best characters by which the species are to be distinguished. The following table shows the characters revealed by the species we recognize.

Abactinal interradiat areas, at least when cleaned, more or less distinctly green . . . . .	<i>Dufresnii</i> .
Abactinal interradiat areas not at all green.	
Oculars large, usually 2, and often 3, in contact with periproct; rarely in small specimens there may be none fully insert; size large, h. d. usually 50-65 mm. and often up to 75 . . . . .	<i>spatuligera</i> .
Oculars small, all distinctly exsert, or rarely one insert; size moderate, usually 30-45 mm., rarely up to 60.	
Primary tubercles numerous, 4-7 well-developed ones on each coronal plate at ambitus in specimens over 30 mm. h. d.; bare abactinal interambulacral spaces usually indistinct or wanting . . . . .	<i>lixula</i> .
Primary tubercles fewer, seldom more than 3 well-developed ones on a coronal plate at ambitus even in large specimens; bare abactinal interambulacral spaces usually more or less distinct.	
Plates of abactinal system and bare interambulacral areas so finely granular as to have an almost velvety appearance, and prettily marked with deep red in contrast to the gray or whitish ground color . . . . .	<i>stellata</i> .
Plates of abactinal system and upper interambulacral plates coarsely granular, not marked with deep red in contrast with the ground color . . . . .	<i>punctulata</i> .

None of the species of this genus were taken by the "Albatross," but they are included here in order that an account of their pedicellariæ may be given.



**Arbacia Dufresnii** Gray.

**Echinus Dufresnii** Blainville, 1825. Dict. Sci. Nat., XXXVII, p. 76.

**Arbacia Dufresnii** Gray, 1835. Proc. Zool. Soc. London, p. 38.

Plate 47, figs. 1-11.

The tridentate pedicellariæ (fig. 1) are rather infrequent and occur chiefly on the actinal surface, though some occur at the ambitus. They appear to be wanting in young individuals. The valves (fig. 5) are broad, rather flat, and rounded at tip. They measure from .70 to 1 mm. in length, and are attached to the stalk by a "neck" of about half that length. The stalk itself is from 2.5 to 3.5 mm. long.

The oplicecephalous pedicellariæ (fig. 2) are very abundant on the ambulacra, among the spines on the interambulacra, and on the buccal plates. A few may occur on the ocular plates. The valves (figs. 7-9) are short, broad, and rounded at the tip, and differ from each other in the size and form of the articular loop. They measure from .50 to .75 mm. in length, and are attached to stalks 4-6 times as long. There is no "neck," but the upper end of the stalk is slightly expanded.

The triphyllous pedicellariæ (fig. 3) are rather scarce, but are to be found on the bare parts of the interambulacra, and rarely on the genital plates. The valves (fig. 6) are broad and flat, rounded at the end, with no "cover-plate," but with a slight articular loop. They measure from .20 to .40 mm. in length, and are attached to the stalk by a neck nearly twice as long. The stalk is from 1 to 1.3 mm. in length.

Calcareous particles appear to be quite wanting in the walls of the pedicels, except for the terminal rosettes and their supporting rods in those of the actinal surface, but large, flat, perforated plates occur in the gills.

The sphaeridia are large and nearly globular.

**Arbacia spatuligera** A. Ag.

**Echinus (Agarites) spatuliger** Valenciennes, 1846. Voy. Venus, Pl. 5, fig. 2.

**Arbacia spatuligera** A. Agassiz, 1872. Rev. Ech., pt. 1, p. 93.

Plate 48, figs. 15-19.

The tridentate pedicellariæ are abundant in some specimens but rare in others. They are very variable in form and size, but resemble those of

*lixula*. The valves (fig. 15) are broad, rounded at the tip, and often have a marked notch on each side just above the base; they range from .25 to 1 mm. in length.

The ophicephalous pedicellariæ resemble those of *punctulata*, and cannot be certainly distinguished from them. The heads of the stalks (fig. 18) are, however, not constricted.

The triphyllous pedicellariæ are rare. They have very broad valves (fig. 16), about .25 mm. long, and are difficult to distinguish from the smallest tridentate pedicellariæ.

The calcareous particles in the pedicels (fig. 17) resemble those of *punctulata*, but are stouter and rougher. Those of the gills are also similar to those of *punctulata*, but are remarkable for the fact that they often carry pedicellariæ.

The sphæridia (fig. 19) are like those of *punctulata*.

#### **Arbacia lixula** Lovén.

*Echinus lixula* Linnæus, 1758. Sys. Nat., p. 664.

*Arbacia lixula* Lovén, 1887. Ech. desc. by Linn., p. 112.

Plate 48, figs. 10-14.

The tridentate pedicellariæ are very variable in size and number, but are generally small, and actinal in position. The valves are very wide in proportion to the length, which ranges from .25 to .95 mm.; they may be bluntly pointed (fig. 10) or more or less rounded at the tip (figs. 11 and 12).

The ophicephalous pedicellariæ are common, especially actinally. The valves (fig. 14) are much narrower than in *punctulata* and less rounded at the tip. They measure about .50 mm. in length, while the stalks are 2 or 3 mm. long. The heads of the stalks are often somewhat constricted as in *punctulata*.

The triphyllous pedicellariæ are very scarce. The valves (fig. 13) are considerably more constricted than in *punctulata*.

Calcareous particles in the pedicels are like those which occur in *punctulata*, but the perforated plates in the gills are more like those of *Dufresnii*.

The sphæridia are like those of *punctulata*.

**Arbacia stellata** Gray.

**Echinus stellatus** Blainville, 1825. Diet. Sci. Nat., XXXVII, p. 76.

**Arbacia stellata** Gray, 1835. Proc. Zool. Soc. London, p. 38.

Plate 48, figs. 20, 21.

The tridentate pedicellariæ appear to be wanting, for none were found in the ten specimens examined.

The ophicephalous pedicellariæ, which resemble those of *lirula*, vary greatly in abundance in different specimens. They also vary considerably in size, the length of the head ranging from .35 to .65 mm. The heads of the stalks are often somewhat constricted as in *punctulata*.

The triphyllous pedicellariæ are scarce and small, the valves (fig. 20) measuring only .25 mm. in length. The latter are remarkably narrow, more slender even than those of *punctulata*.

The calcareous particles in the pedicels seem to be very characteristic, for in all the specimens examined large, swollen, knobbed, and perforated plates (fig. 21) were found. These are sometimes numerous and sometimes few, and it is possible that they are sometimes wanting. The plates in the gills are flat and smooth, as in *Dufresnii*.

The sphæridia are like those of *punctulata*.

**Arbacia punctulata** Gray.

**Echinus punctulatus** Lamarek, 1816. Anim. s. Vert., III, p. 47.

**Arbacia punctulata** Gray, 1835. Proc. Zool. Soc. London, p. 38.

Plates 47, figs. 17-19 ; 48, figs. 1-9.

The tridentate pedicellariæ are abundant in some southern specimens, but are usually infrequent, and in northern specimens are often entirely wanting. They are to be found, when present, chiefly on the actinal surface. They are very variable in size, the valves ranging from .20 to 1.30 mm., and also show considerable diversity of form. They intergrade with the triphyllous pedicellariæ very clearly. The valves are either broad and regularly tapering to a blunt point (Pl. 48, fig. 2), or narrower and distinctly constricted near the middle (Pl. 48, fig. 1).

The ophicephalous pedicellariæ are common, but chiefly actinally and particularly on the buccal plates; they are abundant abactinally only in occa-

sional specimens. The valves show great diversity in form, but are convex or rounded at the tip; they may be greatly constricted near the middle (Pl. 48, fig. 6) or not at all so (Pl. 48, fig. 5). They are .40-.60 mm. in length, and the stalk is 3-6 times as long. The heads of the stalks (Pl. 47, fig. 18) nearly always show a more or less evident constriction which is quite characteristic.

The triphyllous pedicellariæ are very scarce and small, the valves (Pl. 48, fig. 4) measuring only .20-.30 mm. in length.

The pedicels, at least those of the actinal surface, in addition to the terminal rosettes and supporting rods (Pl. 48, figs. 7, 8) are provided with very characteristic straight rods (Pl. 48, fig. 9), which are expanded and more or less perforated at the middle. The gills have large, more or less irregular, knobbed and perforated plates or spheroidal masses of lime (Pl. 47, fig. 19), and similar but larger plates occur in the buccal membrane. These latter are so large that they sometimes carry pedicellariæ.

The sphæridia are somewhat ellipsoidal, usually distinctly wider than long.

#### TETRAPYGUS.

L. Agassiz and Desor, 1846. Cat. Rais., Ann. Sci. Nat. (3) VI, p. 354.

Type-species, *Echinus niger* Molina, 1782. Saggio St. Nat. Chili, p. 175.

The peculiar structure of the ambulacra in this genus has been well worked out and figured by Duncan and Sladen (1885), and appears to warrant its separation from Arbacia. Their attempt to attach Desmoulins' old name (*Echinocidaris*) to it is, however, perfectly futile, for *Echinocidaris* is as complete a synonym of *Arbacia* as could be found, and therefore, of course, cannot be used in any other sense. Desmoulins himself recognized this fact, but sought to maintain his name on the ground of priority. As a matter of fact, Gray's name was published in April, and not in October as Desmoulins asserts. Lovén (1887) attempts to maintain *Echinocidaris* on the ground that the first species mentioned by Desmoulins is *niger*, although he calls it *pustulosa*. This appears to be a pure assumption, however, and quite unwarranted, so that the name *Echinocidaris* must be abandoned, notwithstanding Duncan's (1891) redefinition of it. The name *Tetrapygus* is, however, available, for while the definition given by Agassiz and Desor is not based on the structure of the ambulacra, the first species mentioned is *niger*, and that may well be considered the type.



The only species of this genus known is the common littoral urchin of Chili and Peru, to which Molina gave the name *Echinus niger*. The peculiarities of the ambulacra are evident even in very small specimens.

**Tetrapygyus niger** Agass.

*Echinus niger* Molina, 1782. Saggio St. Nat. Chili, p. 175.

*Tetrapygyus niger* Agassiz, 1846. Ann. Sci. Nat., VI, p. 354.

Plate 47, figs. 12-16.

The tridentate pedicellariæ are small and scarce, and are found only on the actinal surface. The valves (fig. 12) are more slender than in *A. Dufresnii*, and are distinctly constricted near the middle. They measure from .25 to .85 mm. in length, while the stalks on which they are borne are 5-15 times as long.

The ophicephalous pedicellariæ are abundant everywhere, particularly on the buccal membrane. They are very characteristic, for the valves (fig. 14) are usually flattened or even concave at the tip, and have a broad and deeply grooved apophysis, while the head of the stalk (fig. 13) is swollen but contracted at the tip. The valves measure from .25 to .75 mm. in length, and the stalks are 3-20 times as long. Intermediate forms between the ophicephalous and tridentate pedicellariæ are not uncommon.

The triphyllous pedicellariæ are very scarce, and are not peculiar. The heads measure .35 mm. in length, and the stalks are about nine times as long. All the pedicellariæ are purple in color in adult specimens.

There seem to be no calcareous particles in the pedicels, except the usual terminal plates and their supporting rods in those of the actinal surface, but the plates in the gills are numerous and large, with from 10-60 perforations. Similar but larger plates occur in the buccal membrane.

The sphæridia (figs. 15, 16) in young individuals are approximately globular, but in large specimens they are wider than long, and may even become somewhat angular.

PODOCIDARIS.

A. Agassiz, 1869. Bull. M. C. Z., I, p. 258.

Type-species, *Podocidaris sculpta* A. Agassiz, 1869. Bull. M. Z. C., I, p. 258.

The establishment of *Pygmæocidaris* and *Habrocidaris* leaves this a monotypic genus, containing only the species which has been taken a

number of times, but not commonly, off southern Florida and among the West Indies, at depths of 134-400 fathoms.<sup>1</sup>

**Podocidaris sculpta** A. Ag.

*Podocidaris sculpta* A. Agassiz, 1869. Bull. M. C. Z., I, p. 258.

Plate 49, figs. 1-8.

This species was not taken by the "Albatross," but is included for its pedicellariæ.

The tridentate pedicellariæ are small and infrequent, occurring chiefly near or below the ambitus. The valves are broad and not much flattened, and are either somewhat pointed (fig. 6) or almost square-cut (fig. 7) at the tip. They are only about .30 mm. long.

The ophicephalous pedicellariæ are abundant, at least abactinally, and some of them at least are as large as the tridentate. The valves (figs. 4, 5), which are about .30 mm. in length, are strongly constricted above the middle and rounded at the tip, with a more or less sharp corner on each side. The apophysis is very broad, and although it forks where the valve is constricted and passes into the margin on each side, a certain portion of it continues to the tip of the valve. The upper end of the stalk is very markedly constricted (fig. 2).

The triphyllous pedicellariæ are relatively very large, and are scarcely to be distinguished from the tridentate, though the valves (fig. 8), which are about .18 mm. long, are proportionately wider and less constricted.

The calcareous deposits in the pedicels are quite common. They consist of small rods (fig. 3), nearly straight, rounded at the ends, flattened and with a single perforation at the middle. They are about .15 mm. long, and probably lie at right angles to the axis of the foot, in life.

The sphæridia (fig. 1), of which there is a single one at the actinal end of each ambulacrum, are wider than long, and are little or not at all sunken in any depression in the test.

<sup>1</sup> In Mem. M. C. Z., XXXI, "Panamic Deep Sea Echini," heading of Explanation of Plate IX, for "*Podocidaris Cobosi*" read "*Porocidaris Cobosi*."

## DIALITHOCIDARIS.

A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 75.

Type-species, *Dialithocidaris gemmifera* A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 75.

This monotypic genus is still known only from the single specimen collected by the "Albatross" in 1891, off Mariato Point, Panama, in 1793 fathoms.

***Dialithocidaris gemmifera* A. Ag.**

*Dialithocidaris gemmifera* A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 75.  
1904, Mem. M. C. Z., XXXI, p. 56; Pls. XV, figs. 3-5; XXIII.

Plate 46, figs. 9-16.

Although not taken by the "Albatross" since 1891, we include this species in order to describe and figure the pedicellariæ.

The tridentate pedicellariæ (fig. 9) are common, as many as 4-6 occurring on each of the coronal plates. They are very large in proportion to the diameter of the test. The valves (figs. 10 and 11) are strongly compressed, especially just above the apophysis, and are coarsely serrate. They measure from 2 to 2.5 mm. in length, while the stalks are twice as long. The upper end of the stalk (fig. 12) is flattened and expanded.

The ophicephalous pedicellariæ (fig. 13) are abundant, particularly near and upon the abactinal system. The valves (figs. 14, 15) are stout, almost flattened at the tip and strongly constricted near the middle. They are only .30-.45 mm. long, while the stalks may be 6-8 times that length.

The triphyllous pedicellariæ are much less common than either of the other kinds. The valves (fig. 16) are somewhat flattened and rounded at the end; they measure .35-.40 mm. in length, and the stalks are 6-8 times as long.

The calcareous deposits in the pedicels seem to be very scarce. They are simple, perforated plates, so narrow as to be hardly more than flat rods with irregular margins, and little or not at all curved.

The sphæridia are situated one in each ambulacrum, on the peristome, and are not in a marked depression, though the test behind each is slightly hollowed.

## PYGMÆOCIDARIS.

Döderlein, 1905. Zool. Anz., XXVIII, p. 622.

Type-species, *Podocidaris prionigera* A. Agassiz, 1879. Proc. Am. Acad., XIV, p. 199; 1881, "Challenger" Echini, p. 59; Pl. XXXIV, figs. 14, 15.

This is still another monotypic genus, the characters of which have been well discussed by Döderlein (1906), who points out some remarkable similarities between it and the notable genus *Tiarechinus*. It has so far been found only in the East Indian region, at depths of 372-1534 fathoms. It seems clear to us that the specimens collected by the "Siboga" and called by de Meijere "*Podocidaris spec.*" are not only not *prionigera*, as Döderlein lists them, but are not even congeneric with it.

## HABROCIDARIS.

A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 234.

Type-species, *Podocidaris scutata*, A. Agassiz, 1880. Bull. M. C. Z., VIII, p. 72.

This genus, established for *Podocidaris scutata* A. Ag., from the West Indies, also includes the closely allied species, *H. argentea*, from the Hawaiian Islands. It is evident from the peculiar structure of the actinal interambulacral system of *Podocidaris* and its allies that we are justified in separating *P. scutata* A. Ag. from *Podocidaris sculpta* A. Ag., and that we must agree with Döderlein also in separating the remarkable *Podocidaris prionigera* A. Ag. as a distinct genus, allied to *Tiarechinus*, under the name of *Pygmæocidaris*.

*Habrocidaris* A. Ag. and Cl. is more closely allied to *Pygmæocidaris* Död. than to *Podocidaris* as now limited, which in the arrangement of its interambulacral tubercles retains more its *Arbacia*-like characters than do these other genera.

Characteristic of *Habrocidaris* is the very thin, delicate test, the slightly indented peristome, the close plating of the actinal system, and the distinctly triangular primary radioles.

While studying the permanence of the odd actinal interambulacral primordial plate among the regular Echini, one of us, as far back as 1883,<sup>1</sup> was struck with the possible affinity of the *Arbaciadæ* to *Tiarechinus* Neumayr,

<sup>1</sup> "Blake" Echini, Mem. M. C. Z., X, No. 1, p. 22.



and attempted further to trace out this affinity in old and young Arbaciadæ by showing the permanence of this plate in *Dialithocidaris*<sup>1</sup> and in *Arbacia stellata*.<sup>2</sup>

Our attention was again called to the subject by Döderlein's interesting discovery<sup>3</sup> of the existence of a well-developed primordial interambulacral plate in *Podocidaris prionigera* A. Ag., for which he established the genus *Pygmæocidaris*. He furthermore found that the interambulacral zones consist at the base of three plates much as in *Tiarechinus*. *Pygmæocidaris* seems to be slightly more developed than *Tiarechinus*, however, having beyond the row of three plates, interambulacral zones with two rows of plates. This led us to examine again *Podocidaris sculpta* and *Habroecidaris scutata*<sup>4</sup> in connection with the new *H. argentea* from the Hawaiian Islands, and to our gratification we found that in all the primordial plate is as fully developed as in *Pygmæocidaris prionigera*. The details of this primitive structure in *H. argentea* and *H. scutata* are fully shown on Pl. 54, figs. 1-4, 6, 7 of this Memoir. Neither of these species, however, has the third interambulacral plate with a large tubercle immediately above the primordial plate, as shown by Döderlein in figs. e, f, p. 184, of the "Valdivia" Echini. Yet we can agree fully with Döderlein's view of the affinity of these interesting species of Arbaciadæ, as well as of the family, to the Triassic *Tiarechinus*.



FIG. a.

On re-examination of a specimen of *Podocidaris sculpta* 7 mm. in diameter we find that the primordial plate (figs. a, b) extends abactinally so as to separate the first two pairs of interambulacral plates, slightly encroaching upon the third pair, while in *Habroecidaris* it separates only the first pair slightly encroaching upon the second pair. The primordial plate is not cut into two plates as it is figured for *Pygmæocidaris* by Döderlein, pp. 184, 185, "Valdivia" Echini. Seen from the interior of the test, fig. a, the primordial plate only separates the first pair of interambulacral plates and encroaches upon the second

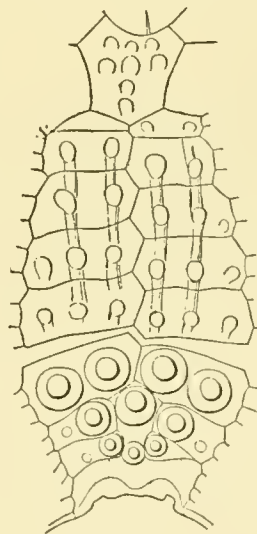


FIG. b.

<sup>1</sup> Panamic Deep Sea Echini, Mem. M. C. Z., XXXI, Pl. 23, figs. 1, 4, 6.

<sup>2</sup> Mem. M. C. Z., XXXI, Pl. 51, figs. 5, 6.

<sup>3</sup> "Valdivia" Echini, p. 182 (figs. p. 183).

<sup>4</sup> Collected by the "Blake" off Santa Cruz, in 580 fathoms.

pair. This difference is due to the slanting of the sutures upon passing through the test. *Dialithocidaris* (Pl. 23, Panamic Ech.) is more closely allied to *Podocidaris* than to any other of the *Arbaciadae*, while the crowding of the poriferous zones at the ambitus allies it more to *Arbacia* than to such genera as *Habrocidaris*, *Pygmæocidaris* and *Podocidaris*.

In *Podocidaris sculpta*, in a specimen measuring 11.75 mm. in diameter, there are, beginning at the actinal system, five and four primary ambulaeal tubercles. In the interambulaeal system the primary tubercles are arranged in transverse rows of three small ones, four somewhat larger, four still larger, five still larger at the ambitus, with a central odd primary in the median line, and the next and last row with only one large tubercle in the outer angle of each interambulaeal plate, a much more *Arbacia*-like arrangement than that of the species once associated as *Podocidaris*.

The two species of this genus are distinguished from each other as follows:

Abactinal system, about .60 h. d.; actinostome distinctly pentagonal . . . . . *argentea*.  
Abactinal system, .50-.55 h. d.; actinostome circular . . . . . *scutata*.

### ***Habrocidaris argentea* A. Ag. and Cl.**

***Habrocidaris argentea* A. Agassiz and Clark, 1907.**

Bull. M. C. Z., L, p. 234.

Plate 49, figs. 9-14; 54, figs. 1-3.

A single specimen of this species was collected by the "Albatross" near French Frigate Shoal. Its diameter is 11.5 mm., that of the actinal system 7 mm., of the anal 2 mm., and of the abactinal 4 mm. Unfortunately all the primary radioles are broken and only the basal portions of a few remain attached to the test. The radioles, like those of *H. scutata* (Pl. 54, figs. 8 and 9), are triangular in cross section, and the three edges though rounded project conspicuously from the solid axis. The test is silvery, tinged with brown, and the primary radioles were evidently white. This species is closely allied to *H. scutata* (Pl. 54, figs. 4, 5) from which it differs in having a distinctly pentagonal, slightly indented actinal system and larger actinal plates (Pl. 54, fig. 1) with comparatively large and prominent poriferous plates, while in *H. scutata* (Pl. 54, fig. 4) the actinal poriferous pairs of plates are very small, scarcely distinguishable from the great number of small angular plates covering the actinal system. In both species the abactinal system is distinctly

pentagonal, somewhat more markedly so in *H. argentea* (Pl. 54, fig. 2). It is but sparsely covered with small, sessile granules which become somewhat club-shaped on the three upper abactinal plates of each interambulacrum. There are five anal plates. The genital plates are elongated, each with one small genital pore. The pore of the madreporic genital is somewhat larger and placed nearer the centre of the plate than in the other genitals where it is close to the anal system.

There are only five primary interambulacral plates (Pl. 54, fig. 3) on each side of the median line above the large, odd, primary interambulacral plate. This is irregularly heptagonal, elongate with concave lateral sides and a broad actinal base slightly indented; it carries one small primary tubercle in the centre of the plate (Pl. 54, fig. 1). This plate separates the next pair of ventral interambulacral plates, each of which has a single primary tubercle near the upper suture. The next pair of plates join along the median line, and each carries a large primary tubercle close to the ambulacral edge of the plates. Riding across the median suture is a large primary tubercle, above which the interambulacral plates bear only minute, scattered, somewhat club-shaped granulations (Pl. 54, figs. 2, 3).

In the ambulacral areas (Pl. 54, figs. 1, 2) the first four or five pairs of plates are narrow with a slight pit near the sutures, carrying the pores. A similar depression in the median line in the angles of the first two pairs of ambulacral plates contains the sphæridium. The next three plates each carry near the centre a primary tubercle, the largest of which is on the upper plate. The pores of these and the six or seven small primitive plates are not in pits, each pair of pores with one exception in the angle of each plate (Pl. 54, fig. 2). On each of these upper plates there are but two or three minute granules.

The tridentate pedicellariæ are rare and occur only near the ambitus. The valves (Pl. 49, fig. 14) are about .38 mm. long, narrower than in *scutata*, more rounded at the tip, and the branches of the apophysis nearly reach the margins of the valve.

The ophicephalous pedicellariæ are abundant abactinally and have very long stalks. The valves (Pl. 49, figs. 12 and 13) are about .28 mm. long, much narrower and more slender than in *scutata*, but of the same general pattern. The upper end of the stalk (Pl. 49, fig. 10) is slightly different.

The triphyllous pedicellariæ are apparently wanting.

The calcareous deposits in the pedicels (Pl. 49, fig. 11) are similar to those in *scutata*, but are smaller and more slender.

The sphæridia (Pl. 49, fig. 9) are a trifle longer than wide. Their position and arrangement are the same as in *scutata*.

This species was taken only at:

Station 3973. Near French Frigate Shoal; 23°47'10" N., 166°24'55" W.  
Bott. temp. 41°. 395-397 fathoms. Crs. co. s. sh. co. r.

### **Habrocidaris scutata** A. Ag. and Cl.

*Podocidaris scutata* A. Agassiz, 1880. Bull. M. C. Z., VIII, p. 72.

*Habrocidaris scutata* A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 234.

Plate 49, figs. 15-20; 54, figs. 4-9.

This species was not taken by the "Albatross," but is included for comparison with the preceding.

The test of the specimen figured in plate 54 is silvery with a brownish tinge. The diameter is 17.5 mm., height 9 mm. The striation of the plates, so marked in the abactinal system of *Salenia*, and on some of the abactinal coronal plates of *Dialithocidaris* and of youthful stages of *Arbacia*, is slightly seen in *H. argentea*, but is very marked in *H. scutata*. The short club-shaped granules of the abactinal parts of the test are irregularly scattered over the abactinal system (Pl. 54, fig. 5). They are far more numerous than in *H. argentea*, and on the abactinal interambulacral plates they are arranged in irregular lines parallel to the sutures. These lines are most prominent at the equatorial belt (Pl. 54, fig. 5), but have nothing of the prominence and regularity which distinguishes *Podocidaris*. The abactinal system is pentagonal, but less so than in *H. argentea*, the genital plates shorter and the ocular plates comparatively larger and higher (compare figs. 5 and 2, Pl. 54). The madreporic genital is the largest and has its pore placed in a slightly raised protuberance much as in *Tiarcchinus*.<sup>1</sup> There are five anal plates. The actinal ambulacral plates are chiefly compound plates only one or two of the four or five which carry no tubercles (Pl. 54, fig. 4), being simple plates as in *P. argentea* (Pl. 54, fig. 1). In two of the ambulacra one of the actinal plates carries a minute tubercle, while on each of the next five plates a large tubercle is found near the lower median angle of the plate (Pl. 54, figs. 4, 6). The plates are provided with three (or rarely four) pairs of pores.

<sup>1</sup> See p. 184, fig. a, Död. "Valdivia" Echini.



The remaining 6 or 7 abactinal ambulacral plates have one or two pairs of pores and each of the larger plates carries a diminutive granular tubercle.

The arrangement of the primary interambulacral tubercles is well shown in Pl. 54, figs. 4, 5, 7. The single primordial interambulacral actinal plate carries from two to four minute granular tubercles, while that of *H. argentea* (Pl. 54, figs. 1, 3) carries a small primary tubercle.

The pairs of pores of the actinal ambulacral plates are sunken in small pits as in *H. argentea* and in the median line there is the larger sphæridial depression seen in that species.

The tridentate pedicellariæ are not uncommon, especially near the ambitus. The valves (Pl. 49, fig. 19) are very broad and flat, with nearly parallel sides and almost truncate tip. The apophysis is narrow and forks widely at the end, but the two divisions do not reach the margins of the valve. The length of the valve is about .40 mm., while its width is nearly one-half as much.

The ophicephalous pedicellariæ are very characteristic and are remarkable for the very great constriction of the valves (Pl. 49, fig. 17) just above the middle and the peculiar widening and hollowing of the apophysis. The articular loop (Pl. 49, fig. 18) of the chief valve is relatively very large. The valves are about .30 mm. in length, while the stalks are 6-8 times as long. The upper end of the stalk (Pl. 49, fig. 16) is very rough, obliquely truncate and slightly constricted.

The triphyllous pedicellariæ are apparently wanting.

The calcareous particles in the pedicels are straight rods (Pl. 49, fig. 20) with blunt tips. They are expanded at the middle and perforated there with from one to four small holes. They are relatively very long (.40-.70 mm.) and presumably lie horizontally in life, though they are more or less oblique or even vertical in dried pedicels.

The sphæridia (Pl. 49, fig. 15) are proportionately large and are nearly as long as wide. There is one in each ambulacrum, at the peristome, and it lies on the surface of the test, in only a very slight depression.

The type and only known specimen of this species was taken by the "Blake" off Santa Cruz, Danish West Indies, in 580 fms.

## CÆLOPLEURUS.

Agassiz, 1840. Cat. Sys. Ectyp. Ech., p. 19.

Type-species, *Cidaris coronalis* Leske, 1778. Add. Klein, p. 72.

Tertiary and Recent Arbaciadæ.

The considerable amount of material which we have been able to examine, including specimens collected by the "Challenger," "Blake," "Albatross," and "Siboga," besides Michelin's type of *Maillardi*, has satisfied us that at least five recent species of this genus must be recognized. The specimens collected by the "Siboga" appear to be identical with Michelin's species, which accordingly ranges from Mauritius to the Kei Islands in 38-120 fms. The "Blake" specimens are all *floridanus* A. Ag., which is found throughout the West Indian region in depths of 56-1323 fms. Whether the specimen from Agulhas Bank, off the southeastern coast of South Africa, collected by the "Valdivia," and identified by Döderlein as *floridanus*, is really identical with the West Indian species seems to us open to doubt. The *Saleniæ* taken in the same locality and called *Pattersoni* by Döderlein is certainly not the West Indian species, and it seems highly improbable that the specimen of *Cælopleurus* should belong to the Caribbean fauna. The "Albatross" specimens are all *maculatus* A. Ag. and Cl., while those taken by the "Challenger" appear to have been in part *maculatus*, and in part a hitherto undescribed species to which we have given the name *longicollis* on account of the extremely long collar on the fully developed primaries. The specimens of *longicollis* were taken in Basilan Straits, Philippine Islands, in 82-102 fms. while *maculatus* was taken at Amboina, by the "Challenger," in 100 fms. and off western and southern Japan, by the "Albatross," in 40-59 fms. There is also a specimen of *maculatus* from the Uraga Channel, Gulf of Tokyo (East Coast of Japan), 70 fms., in the M. C. Z. collection. The fifth species which we consider it necessary to recognize is the handsome form brought by Dr. Willey from New Britain, called by Bell (1899) "*Salmacis? elegans*," but which, as de Meijere (1904) has pointed out, is so obviously a *Cælopleurus*, it seems odd that Bell failed to recognize the genus. Assuming that the colored drawings are accurate, this species is characterized by stout primaries with a very short collar, that taper very little and are apparently not curved, as well as by its unusual coloration.

The recent species of this genus are remarkable for their striking colors, as well as for their slender, curved primary spines. The slenderness and

curvature of the primaries is not so marked in small specimens as in the large ones, and the peculiarity of *elegans* in these particulars may be due, in part at least, to the small size of the specimen, which is only about 10 mm. h. d. Aside from the obvious differences in color, the species are distinguished from each other by the characters of the collar on fully developed primaries and the form of the valves of the ophicephalous pedicellariæ. The following table will make these differences clear, it being understood that only unbroken, fully developed spines from the interambulacra, at or near the ambitus, of mature specimens, are meant, when "primaries" are referred to; when "length" of valve is mentioned in connection with pedicellariæ, it is understood that the "articular loop" is *not* included in the measurement.

Primaries spotted or banded, at least on basal half; collar less than ten per cent of length of spine.

Markings on primaries distinctly purple; ground color green; collar about eight per cent of spine-length, finely granular, without conspicuous longitudinal ridges but with distal margin oblique; valves of ophicephalous pedicellariæ decidedly constricted, the least width of blade not more than .40 of length of valve . . . . . *Maillardi.*

Markings on primaries bright red; collar about five per cent of spine-length.

Ground color of primaries bright green; collar rough with 12-15 conspicuous longitudinal ridges and with distal margin horizontal; valves of ophicephalous pedicellariæ not greatly constricted, the least width exceeding .60 of length . . . . . *maculatus.*

Ground color of primaries bright yellow; character of collar and pedicellariæ unknown . . . . . *elegans.*

Primaries not spotted or banded except occasionally on distal half; collar more than ten, often more than twenty per cent of spine-length, rough with finely serrate longitudinal ridges.

Primaries more or less uniformly red, at least on abactinal surface; collar extends distinctly farther on abactinal ridge than on sides of spine; valves of ophicephalous pedicellariæ decidedly constricted, the least width not exceeding .50 of length . . . . . *floridanus.*

Primaries more or less uniformly whitish, sometimes with spots of red distally; collar does not extend distinctly farther on abactinal ridge than on sides of spine; valves of ophicephalous pedicellariæ not constricted, the least width exceeding .70 of length . . . . . *longicollis.*

**Cœlopleurus Maillardi** A. Ag.

**Keraïaphorus Maillardi** Michelin, 1862. Maillard's Bourbon. Annéx. A, p. 2; Pl. XIV.

**Cœlopleurus Maillardi** A. Agassiz, 1871. Bull. M. C. Z., II, p. 456.

Plates 49, fig. 34; 53, figs. 8, 9.

Although small specimens (6–19 mm. in diameter) of what appears to be this species were taken in considerable numbers by the "Siboga" in the Dutch East Indies, de Meijere (1904) gives no figures or description of the pedicellariæ. Thanks to Dr. Weber of the Amsterdam Museum, the Museum of Comparative Zoölogy received in exchange one of these "Siboga" specimens, and there is little reason to doubt the correctness of de Meijere's identification. These young specimens, however, show only indistinctly the peculiar, nearly horizontal markings on the bare, abactinal, interambulacral spaces, so clearly shown in Michelin's figures. These bare areas are purplish-blue in the "Siboga" specimens, and there is far less of a reddish tinge on the abactinal parts of the test than is indicated by Michelin. These slight differences may well be due to the difference in size, as Michelin's specimen was 42 mm. in diameter.

The tridentate pedicellariæ show no peculiarities, resembling those of *floridanus*, but the ophicephalous are remarkable for their very slender, highly constricted valves, resembling far more closely those of *floridanus* than they do those of either *maculatus* or *longicollis*. The valves of the tridentate pedicellariæ are colorless, and measure .18–.90 mm. in length. The valves of the ophicephalous pedicellariæ are lightly colored with greenish and reddish as in *maculatus*, but much less markedly so; they are .20–.45 mm. in length. The small size of the pedicellariæ is doubtless due, at least in part, to the small size of the specimen from which they were taken, the test of which was only about 10 mm. in diameter. The calcareous particles and spheridia showed no peculiarities.

**Cœlopleurus maculatus** A. Ag. and Cl.

**Cœlopleurus maculatus** A. Agassiz and Clark, 1907. Bull. M. C. Z., LI, p. 116.

**Cœlopleurus Maillardi** A. Ag. "Challenger" Echini, p. 60 (*partim*). Pls. V, fig. 3; VI, figs. 8–14 (non Michelin).

Plates 49, figs. 21–28; 53, figs. 1–7; 57, figs. 4–6.

In the "Challenger" Echini Report (pp. 60–64) a number of specimens of *Cœlopleurus* collected at Amboina and in the Philippines were referred to



*Cælopleurus Maillardi*. This identification is not correct, the specimens alluded to belonging in part to a new species which we have called *Cælopleurus longicollis* (q. v.) (described and figured under the name of *C. Maillardi* on Pl. VI of the "Challenger" Echini, and on Pl. V, figs. 1, 2), and in part to the species we have called *Cælopleurus maculatus* ("Challenger" Echini, Pl. V, fig. 3). The latter may be at once recognized by the peculiar ornamentations of the median abactinal part of the interambulacral area which we figure on Pl. 53, figs. 2, 4, of this memoir; this, with the red and green color of the primary spines, at once distinguishes it from all the other species of *Cælopleurus*.

The specimen figured on Pl. 53, figs. 1, 2, measures 24 mm. in diameter and 15 mm. in height; the actinal system is 10 mm. in diameter, the abactinal system 5 mm., and the anal system 4 mm. The greatest width of the interambulacral system is 8 mm., while the greatest width of the ambulacral system is 6 mm. There are ten and ten primary ambulacral tubercles occupying the whole median ambulacral space; the six at the ambitus are the largest, and they diminish in size towards both the actinal and abactinal systems.

The pores are arranged close to the edge of the scrobicular area in irregular arcs of three pairs to each plate. They are largest on both sides of the ambitus (Pl. 53, figs. 1-3). The primary tubercle occupies nearly the whole of each plate with the exception of the small tubercles filling the median ambulacral space. The interambulacral primaries extend only to the seventh plate from the actinal system. Tubercles similar to those in the ambulacral median area occupy the median interambulacral space actinally, and extend in the outer angle of each plate between the primaries and the poriferous zone. Above the primary tubercles the interambulacral plates are covered on the outer sides with a coarse granulation, leaving a straight, narrow, smooth median area ornamented with a bare S-shaped marking. The bare space being whitish is very prominent, the granules which flank it being dark violet in striking contrast. The appearance of this bare interambulacral space (Pl. 53, fig. 2; Pl. V, fig. 3, "Challenger" Echini) is thus very different from what it is in other species of the genus (see the corresponding figures of *Cælopleurus floridanus* A. Ag., "Blake" Echini, Pls. VII, figs. 1, 3; VIII, figs. 1, 4, 7, 10, 11, 14, 15, 16; of *Cælopleurus Maillardi* A. Ag., Michelin, Maillard's Bourbon, Ann. A., Pl. XIV; and of *Cælopleurus longicollis*, A. Ag. and Cl. "Challenger" Echini, Pls. V, fig. 1; VI, figs. 1, 2, 6).

The ambulacral pores near the actinal system are somewhat crowded together; the membrane of the slight actinal cuts extends well up in the angle between the ambulacral and interambulacral areas (Pl. 53, fig. 1). There are from six to nine small but deep actinal sphaeridial pits in the median ambulacral zone.

There are four anal plates, surrounded by a narrow raised ring formed by the genitals (Pl. 53, fig. 2). The genital pores are distal, placed close to the outer angle of the genital plates; the madreporic body is clearly indicated by small pores. The genital plates, which are irregularly heptagonal, carry scattered tubercles of the size of those of the abactinal interambulacral plates (Pl. 53, fig. 2). The ocular plates are pentagonal and are excluded from the anal system.

The actinal system is decagonal, slightly indented in the median ambulacral line, and is closely covered with minute longitudinal plates, among which are placed the five widely separated pairs of buccal plates with their minute pores (Pl. 53, fig. 1).

*Ceolopleurus maculatus* is a strikingly handsome species (Pl. 57, figs. 4-6) with its polished, bright pea-green primary spines conspicuously spotted on the upper side with scarlet red. The lower side is white, with somewhat indistinct red markings, as though the spots on the upper side showed through (Pl. 53, figs. 5, 6, 7). Towards the tip of the spine, on the upper side, the red spots become confluent so that the distal part of the spine is red for a greater or less distance, though it may be tipped with green or white. The primary spines are sharply triangular, especially near the base, and are distinctly curved towards the tip. The collar is short, rarely over 5 mm. in length, dull and usually rough, with four or five longitudinal series of coarse granules, on each side. The small actinal primary spines are flat and smooth, pure white, with very conspicuous gray collars extending half their length. The secondary spines are stout and blunt. In the largest specimen of *C. maculatus*, measuring 37 mm. in diameter, the primary spines are from three to three and a half times the diameter of the test. With the additional material from Japan at our disposal we find that the different species of this genus can at once be readily distinguished by the marking of the abactinal interambulacral area, the coloration of the spines, and the length of the collar. In *C. Maillardi* the primaries are green, marked with deep purple spots. The collar is 8 mm. long and finely and uniformly granular (Pl. 53, figs. 8, 9). In *C. maculatus* the primaries are green, with the spots

bright red. In *C. floridanus* the primaries are uniformly red. In *C. longicollis* the primaries are whitish, with a long collar marked with granular lines (Pl. 53, figs. 10, 11). In *C. elegans*, the primaries are bright yellow, with the spots red.

Döderlein (1906) has given quite a full account of the pedicellariæ and calcareous particles of this species, with some figures ("Valdivia" Echrini, Pl. 45, fig. 1), under the name of *C. Maillardi*. Aside from his statement that the specimen was from Japan, his figure of an ophicephalous pedicellaria shows clearly that he had *maculatus* and not *Maillardi* in hand. It has seemed to us that additional figures were desirable for the sake of comparison with the other species of the genus.

The tridentate pedicellariæ are common, and show considerable diversity of form and size. The valves (Pl. 49, figs. 23, 24) are slender and rounded at the end; their length ranges from .30 to 1.85 mm. They are sometimes tinged with green at the tip, while reddish at the base, but are often colorless. The stalks are 1.5–5 times as long as the valves, and their upper ends (Pl. 49, fig. 25) are enlarged and rounded without any constriction.

The ophicephalous pedicellariæ are abundant, especially actinally. The valves (Pl. 49, fig. 21) are much stouter than in *floridanus*, but are not quite so stout as those of *longicollis*. They are easily distinguished from the latter, moreover, by their evident constriction near the middle. They (i. e., the lime) are usually quite deeply colored, red near the base and green at the tip. The upper ends of the stalks are also colored red. The valves are .60–.70 mm. in length, while the stalks are 3–6 times as long.

The triphyllous pedicellariæ appear to be wanting, unless we call the smallest of the tridentate by that name.

The calcareous particles in the pedicels are irregular, rough, more or less curved rods (Pl. 49, fig. 27), in addition to the usual terminal rosettes and supporting plates. The calcareous particles of the gills (Pl. 49, fig. 28) are smooth perforated plates of small size and irregular form.

The sphæridia are numerous (6–12) in each ambulacrum on the actinal surface. They are decidedly wider than long, and are deeply sunken in pits in the test (Pl. 49, fig. 26).

This species was taken by the "Albatross" at the following stations:

Station 4881. Eastern Channel, Korea Strait. Bott. temp. 64.9°; 40–59 fathoms. Fne. gy. s. br. sh.

Station 4937. In Kagoshima Gulf, Japan. Bott. temp. 64.8°. 58 fathoms. M. lav. p.

Bathymetrical range, 40–59 fathoms. Extremes of temperature, 64.8°–64.9°. Five specimens.

***Cœlopleurus floridanus* A. Ag.**

*Cœlopleurus floridanus* A. Agassiz, 1872. Rev. Ech., Pt. I, p. 102.

Plates 44, figs. 1, 2; 49, figs. 31–33; 53, fig. 11.

This species was not taken by the "Albatross," but is included for comparison with the other species of the genus.

Döderlein (1906, Pl. 45, fig. 2) has given a series of figures illustrating the pedicellariæ and calcareous particles of *floridanus*, but as his specimen came from southeast of the Cape of Good Hope, and is quite possibly *not* this species, it seems desirable to give a few figures of pedicellariæ from a typical West Indian specimen.

The tridentate pedicellariæ are common, and show a remarkable diversity of size and form. The valves measure from .35 to 2.30 mm. in length, and are commonly rosy-red in color, at least along the mid-line. They may be very slender (Pl. 49, fig. 32) or somewhat widened, with a constriction near the middle (Pl. 49, fig. 33). The latter are small, and approach triphyllous pedicellariæ in their general appearance, but intergrade completely with the larger ones. The stalks of the tridentate pedicellariæ are commonly several times as long as the head, but in the large ones the heads may equal or even exceed the stalk. The upper end of the stalk is slightly enlarged and rounded, as in *maculatus*.

The ophicephalous pedicellariæ are very common, especially on the actinal surface. The heads and even the upper end of the stalks are strongly tinged (in the lime itself) with red, but the larger the pedicellaria the paler is the color. The valves (Pl. 49, fig. 31) are somewhat elongate, and are markedly constricted at the middle. They measure about half a millimeter in length, while the stalk is four or five times as long. The upper end of the stalk is flat and expanded, as in *maculatus*.

Triphyllous pedicellariæ appear to be wanting.

The calcareous particles of the pedicels are rough, curved irregular rods like those of *maculatus*, and the perforated plates from the gills cannot be distinguished from those of that species.



The sphaeridia, of which there are from 6 to 12 on each ambulacrum, are wider than long, and are deeply sunken in pits in the test, as in *maculatus*.

**Cælopleurus longicollis** A. Ag. and Cl.

**Cælopleurus Maillardi** A. Agassiz, 1881. "Challenger" Echini, p. 60 (*partim*). Pls. V, figs. 1, 2; VI, figs. 1-7, 15-22.

(Non **Keraſaphorus Maillardi** Michelin, 1862. Maillard's Bourbon. Ann. A, p. 2.)

Plates 49, figs. 29, 30; 53, fig. 10.

We need not describe this species here further than to refer to the description of specimens collected at Station 201, Straits of Basilan, P. I., in the "Challenger" Echini, p. 60, which applies to *C. longicollis*, with the exception of such part as applies to the description of the banded, colored spines, a feature of *C. maculatus* (Pl. V, fig. 3).

The tridentate pedicellariæ are scarcely distinguishable from those of *maculatus*, except that the lime is colorless and the upper end of the stalk (Pl. 49, fig. 30) has a marked constriction near the tip. The valves are .30-2.65 mm. in length.

The ophicephalous pedicellariæ are very characteristic, for not only are they colorless (i. e. the lime), but the valves (Pl. 49, fig. 29) are very broad and not at all constricted, and have a narrow apophysis; they are about two-thirds of a millimeter long.

Triphyllous pedicellariæ are apparently wanting.

The calcareous particles in the pedicels and gills and the sphaeridia are not distinguishable from those of *maculatus*.

**ASPIDODIADEMATIDÆ** Duncan.

THE PEDICELLARIÆ AND OTHER STRUCTURAL CHARACTERS.

Plates 44, figs. 3, 4; 50, figs. 1-15.

Thanks to the descriptions and figures of Mortensen (1904), de Meijere (1904), and Döderlein (1906) the pedicellariæ of this family are very completely known, the only species not examined by any of those writers being *Dermatodiadema horridum* and *globulosum*, which we describe and figure herewith. As we have also examined *D. antillarum* and all of the four species of *Aspidodiadema*, a brief account of the pedicellariæ of the family



will not be out of place. There are no constant differences between the pedicellariæ of *Dermatodiadema* and those of *Aspidodiadema*, but there are such differences between the larger pedicellariæ of some of the species of *Dermatodiadema* which are useful in their identification.

The size and form of the pedicellariæ show an extraordinary diversity, as many as seven different kinds sometimes occurring on a single specimen, while most individuals have at least four. There can generally be found triphyllous, ophicephalous, and tridentate pedicellariæ; in some individuals, two forms of triphyllous occur, while there are very commonly two forms of tridentate present, and there may be three or four. The stalks of the pedicellariæ are calcareous rods, more or less enlarged, and fenestrated at the ends, the extent of the fenestration depending chiefly on the size of the pedicellaria.

The tridentate pedicellariæ in their most common form have the valves long and slender (Pl. 50, figs. 7, 12), usually straight, but sometimes curved; these may be called the "*slender tridentate*." Other very large pedicellariæ are usually present of which the three valves are very broad and deep in proportion to their length and have the blade more or less filled by a calcareous network (Pl. 50, figs. 1, 6, 11). These pedicellariæ are called "globifere" by Döderlein, which is convenient but inaccurate, as they are certainly not homologous with the globiferous pedicellariæ of the other *Diadematoidea*. Mortensen calls them "large ophicephalous," and while in some cases their resemblance to ophicephalous pedicellariæ is apparent, the absence of an "articular loop" and their great size are objections to regarding them as such. As de Meijere calls them "grosse tridentate," and we incline to the view that that name best expresses their real character, we shall designate them as "*stout tridentate*." Although these stout tridentate pedicellariæ usually have the blade rather deep, with the sides converging to a blunt point, they sometimes occur with broad, rather flat blades and wide tips (Pl. 50, fig. 3); such pedicellariæ may be designated as "form *b*." Another peculiar form is rarely found, which is quite intermediate between the tridentate and ophicephalous pedicellariæ, having the "articular loop" of the latter and the blade free from a calcareous network, but with the general appearance of the former (Pl. 50, fig. 4); these may be called "form *c*."

The *slender tridentate* pedicellariæ are very common, and occur on all parts of the test, even on the abactinal system and the buccal membrane. The

heads are attached to the stalks, which are rarely more than twice as long, by a relatively short "neck," and the upper end of the stalk is rounded. The valves (Pl. 50, figs. 7, 12) range in length from .30 to 2.00 mm., and their greatest width does not exceed .40 of the length. They may be straight and meet for nearly their whole length, or else straight or curved and meet only at the tips. The blade is often compressed; it seldom contains much of a calcareous network, only a few transverse pieces. The *stout tridentate* are usually rare and often wanting. They occur chiefly on the abactinal surface, especially close to the genital and ocular plates. The heads are attached to the stalks, which seldom greatly exceed them in length, by a very short neck, and the upper end of the stalk (Pl. 50, fig. 15) is much enlarged and slightly flattened. The valves (Pl. 50, figs. 1, 6, 11) are roughly triangular with a blunt point and are always very deep at the base, but the blade is more shallow and is largely filled by a calcareous network. The valves are from .60 to 2.00 mm. in length, and the breadth at base is from a half to three-fourths of the length. Form *b* is rarely met with, but is sometimes found abactinally. The valves (Pl. 50, fig. 3) are comparatively flat, more oblong than triangular, and the calcareous network is only in the lower part of the blade. The length of the valves is rather more than a millimeter, and the width is about half as much. Form *c* is quite as rare as *b*. The valves (Pl. 50, fig. 4) are only about .50-.60 mm. in length and .20-.25 mm. wide at base, and are remarkable for the presence of an articular loop and the absence of the calcareous network in the blade.

The ophicephalous pedicellariæ are common on all parts of the test, but are chiefly found on the interambulacra. They are remarkable for the very small heads and the presence of three large glands on the stalk. The head rests directly on the enlarged, flattened, or concave end of the stalk, which is 6-10 times its length. The valves (Pl. 50, figs. 9, 14) are only about .20 mm. in length, and their width is a little more than half as much. They may be rounded or pointed at the tip. An articular loop is present, but is small and the three valves do not differ essentially from each other. Döderlein and Mortensen both speak of these pedicellariæ as sometimes having four valves, but we have never seen any with more than three.<sup>1</sup>

<sup>1</sup> Dr. Mortensen's figures (1904, Pl. 4, figs. 10 and 12) represent the valves of ophicephalous pedicellariæ much flatter than they appear to be to us, and with a rudimentary articular loop or none, a condition we have not observed. We may also mention that his figure 35, pl. 4, cannot possibly be a triphyllous valve, as is stated in the explanation of the plates. This is doubtless a slip of the pen for "tridentate."

The triphyllous pedicellariæ are common everywhere on the coronal plates, and are easily recognized by the very slender stalk, several times as long as the head, and the very long neck, about twice the length of the valves. The latter are from .30 to .50 mm. in length and are greatly constricted just above the base. The blade expands at the tip, and is provided with a perforated "cover-plate" which conceals more or less of the basal part. Two quite distinct kinds of triphyllous pedicellariæ are found sometimes on the same individual. In the common kind the valve (Pl. 50, figs. 8, 13) is rounded at the tip, and the greatest width of the blade is 1.25 times the width of the base of the valve or less. In the other kind, which seems to be quite rare, the valve (Pl. 50, fig. 5) is almost square cut at the tip, and its width there is twice that of the basal part. The larger triphyllous pedicellariæ of the common kind intergrade completely with the slender tridentate, the blade becoming elongate and the cover-plate reduced or even practically wanting. Neither tridentate (except form *c*) nor triphyllous pedicellariæ ever have an articular loop.

The sphæridia (Pl. 50, figs. 2, 10) in the Aspidodiadematidæ are either globular or ovoid and never wider than long. They are suspended by short stalks from minute tubercles on the ambulacral plates, and are entirely on the surface, never sunken in depressions or pits. They are remarkably numerous, for a number are always to be found on the actinal half of each ambulacrum, and not infrequently the abactinal half is also provided with them. In some individuals they extend all the way from peristome to ocular plate, as many as fifteen being found in each ambulacrum. They are rather small, however, seldom exceeding .35 mm. in length.

The calcareous particles of the pedicels and gills consist of smooth, perforated plates of comparatively small size and with few holes. In the gills they are quite irregular, but in the pedicels they tend to assume one of two forms: in one the ends are somewhat drawn out, and the perforations are minute and confined to the middle of the plate, while in the other the perforations are larger and occur in all parts of the usually elongated plates. We are unable to draw any sharp line between these two forms, nor can we find that any generic or specific characters are to be drawn from the calcareous particles of any sort.

The arrangement of the internal organs of *Aspidodiadema* are shown in figures 3 and 4, Pl. 44. The reproductive organs are narrow, elongated tufts of rather thick, short tubules, which, when fully developed, occupy

most of the interambulacrum from genital plate to peristome. The œsophagus is rather short, and the lower coil of the stomach-intestine is wide and little undulated, though with large radial pouches in all of the ambulacra except the anterior one. The upper coil of the intestine is somewhat narrower, and is scarcely undulated at all, so that the entire intestine is remarkably short. The rectum is held in position by numerous strands of connective tissue which are attached to the abactinal margin of the corona.

#### THE GENERA AND SPECIES OF ASPIDODIADEMATIDÆ.

The better acquainted we become with this characteristically deep-sea group of recent Echini the stronger becomes the conviction that Duncan was right when he separated them as a distinct family from the Diadematidæ. The group is a very homogeneous one, for while we find it desirable to recognize 10 species, there are only 2 genera, and these are distinguished solely by the not very important but very constant character of the size of the primary tubercles in the lower half of the ambulacra. It is an interesting fact that essentially the same difference distinguishes Diadema and Echinothrix. The two genera of Aspidodiadematidæ are as follows:

- Large primary tubercles present in ambulacra actinally . . . . . *Aspidodiadema*.
- No large primary tubercles present in ambulacra actinally . . . . . *Dermatodiadema*.

#### ASPIDODIADEMA.

A. Agassiz, 1879. Proc. Amer. Acad., XIV., p. 199.

Type-species, *Aspidodiadema tonsum* A. Agassiz, 1879. Proc. Am. Acad., XIV., p. 199.

The four species which we consider it desirable to recognize in this genus are very closely allied to each other, but appear to be constantly distinguishable by the characters given in the table below. One of them, *Jacobyi* A. Ag., occurs in the West Indian region, in 95–287 fms., but the others occur in the Indo-Pacific region, especially its eastern half, in depths of 100–1700 fms. The “Challenger” species, *tonsum* A. Ag., is known from the East Indies and Japan; the “Valdivia” species, *nicobaricum* Död., from the Nicobar and Hawaiian Islands; and the “Siboga” species, *meijerei* Död., from the Kei and the Hawaiian Islands. While *nicobaricum* commonly occurs at depths of over 400 fms., *meijerei* is usually found in water of less than 300 fms.



- Ambulacra broad, about  $\frac{3}{4}$  as wide as interambulacra, or even wider; miliary tubercles rather few actinally, 2-6 on a buccal plate, usually fewer than 10 on larger interambulacral plates, except in the largest specimens (25-30 mm. h. d.).
- Primary spines purple or purplish; test tending to become deep purple actinally . . . . . *nicobaricum*.
- Primary spines green or greenish; test tending to become purple abactinally . . . . . *meijerei*.
- Ambulacra narrower, about  $\frac{2}{3}$  as wide as interambulacra or less; miliary tubercles numerous actinally, 8-12 on a buccal plate, usually more than 10 on larger interambulacral plates.
- Primary spines purplish; anal plates densely covered with rather stout miliary spines . . . . . *tonsum*.
- Primary spines greenish; anal plates each with 5-10 rather slender miliary spines . . . . . *Jacobyi*.

### *Aspidodiadema nicobaricum* Död.

*Aspidodiadema nicobaricum* Döderlein, 1901. Zool. Anz., XXIV., p. 21.

Plate 50, figs. 1, 2.

One needs but to compare the descriptions and figures given by de Meijere (1904), Mortensen (1904), and Döderlein (1906), of the pedicellariæ of this species, to realize how elusive and unsatisfactory a classification based to any considerable extent on these minute structures is sure to be. While the "personal equation" will probably explain some of the differences shown by these writers, it seems to be true that this is a very variable species so far as the pedicellariæ are concerned. Our Hawaiian specimens exhibit certain peculiarities which would seem to distinguish them from East Indian specimens. Thus, we find the ophicephalous pedicellariæ have only 3 valves, while Mortensen and Döderlein say there are 4; however, de Meijere describes and figures them as though there were only 3 in his specimens. Again, none of the Hawaiian specimens have slender, tridentate pedicellariæ with curved valves, as figured by Döderlein; however, he says he missed them in most of the "Valdivia" specimens, so this is not an important difference. Again, some of the Hawaiian specimens have very large, *stout tridentate* pedicellariæ, with valves (Plate 50, fig. 1) over a millimeter and a half in length; however, these are more frequently absent than not, so no great weight can be attached to them. If we sum up all the observations so far made on the pedicellariæ of this species, the result is as follows:



*Slender tridentate* pedicellariæ, abundant, of very variable size and form; usually the valves are straight and meet either for their full length or only at the tip, but in some Nicobarian specimens they are conspicuously curved. The length of the valves ranges from .60 to 1.65 mm., and the margin is either smooth or finely serrate, rarely coarsely dentate.

*Stout tridentate* pedicellariæ, rare and often wanting in Hawaiian specimens, wholly wanting in Nicobarian specimens, common or sometimes infrequent in specimens from the Kei Islands. The valves are either about a millimeter long and nearly as wide, with a tooth at the tip (specimens from Kei), or they are over a millimeter and a half long, only a little more than half as wide, and rounded at the tip (specimens from Hawaii).

*Ophicephalous* pedicellariæ are of the usual form and size, and exhibit little diversity. There are 3 glands on the stalk, and in specimens from Kei and Hawaii there are 3 valves in the head; specimens from Nicobar have 4 valves.

*Triphyllous* pedicellariæ are common, and exhibit no special peculiarities. The valves are relatively narrower at the tip, and the lower part of the blade is thicker in specimens from Kei than in those from either Nicobar or Hawaii.

Such diversity of pedicellariæ naturally suggests the possibility that we are dealing with three different species, but it appears to be impossible to point out any constant character of any kind by which specimens from the three widely separated localities where this species has been taken can be distinguished from each other. Possibly an actual comparison of specimens might reveal some tangible differences, but Döderlein's and de Meijere's descriptions are so detailed they seem to leave no reasonable ground for such an expectation.

This species was taken by the "Albatross" at the following stations:

Station 3892. Off Mokapu Islet, N. coast of Molokai, Hawaiian Islands. Bott. temp. 42.5°. 328-414 fathoms. Fne. gy. s.

Station 3981. Off Nawiliwili Light, Kauai, H. I. 414-636 fathoms. Glob. oz.

Station 3988. Off Hanamaulu, Kauai, H. I. Bott. temp. 40. 165-469 fathoms. Gy. for. s. p.

Station 3989. Off Hanamaulu, Kauai, H. I. Bott. temp. 37.5°. 385-500 fathoms. Co. s. r.

Station 3994. Off Mokuææe Islet, Kauai, Hawaiian Islands. Bott. temp. 42.9°. 330-382 fathoms. Fne. gy. s. for.

Station 4013. Off Hanamaulu, Kauai, H. I. Bott. temp. 41°. 399-419 fathoms. Fne. gy. s. for.

Station 4014. Off Hanamaulu, Kauai, H. I. Bott. temp. 40.8°. 362-399 fathoms. S. for.

Station 4021. Off Hanamaulu, Kauai, H. I. Bott. temp. 44°. 286-399 fathoms. Co. s. for.

Station 4022. Off Hanamaulu, Kauai, H. I. Bott. temp. 41°. 374-399 fathoms. Co. s. for. r.

Station 4025. Off Mokuææe Point, Kauai, H. I. Bott. temp. 44.9°. 275-368 fathoms. Fne. gy. s. br. sh. for.

Station 4030. Off Ukula Point, Kauai, H. I. Bott. temp. 41°. 423-438 fathoms. Fne. co. s. for. r.

Station 4107. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 41.6°. 350-355 fathoms. Co. s. for.

Station 4110. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 40.3°. 449-460 fathoms. Gy. s.

Station 4112. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 40.5°. 433-447 fathoms. Fne. s.

Station 4131. Off Hanamaulu, Kauai, H. I. Bott. temp. 43.7°. 257-309 fathoms. Fne. gy. s.

Station 4137. Off Hanamaulu, Kauai, H. I. Bott. temp. 41°. 411-476 fathoms. Co. vol. s. for. r.

Station 4140. Off Hanamaulu, Kauai, H. I. Bott. temp. 43.4°. 339-437 fathoms. Fne. gy. s.

Station 4141. Off Hanamaulu, Kauai, H. I. Bott. temp. 41°. 437-632 fathoms. Vol. s. for.

Station 4166. Off Modu Manu, H. I. Bott. temp. 45.6°. 293-800 fathoms. Co. s. for. r.

Station 4177. Off Kawahioa Point, Niihau, H. I. Bott. temp. 41°. 319-451 fathoms. Gy. s. glob.

Station 4180. Off Kawahioa Point, Niihau, H. I. Bott. temp. 41°. 417-426 fathoms. P. glob. r.

Station 4187. Off Hanamaulu, Kauai, H. I. Bott. temp. 40°. 508-703 fathoms. Gy. s. for.

Bathymetrical range, 165–800 fathoms, but averaging considerably over 400 fathoms.

Extremes of temperature, 45.6°–37.5°; average temperature, 41.6°.

One hundred and sixty-four specimens.

**Aspidodiadema meijerei** A. Ag. and Cl.

*Aspidodiadema nicobaricum* var. *meijerei* Döderlein, 1906. Echin. Deutsch. Tiefsee-Exp., p. 165.

*Aspidodiadema meijerei* A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 235.

Plates 44, figs. 3 and 4; 58, figs. 7 and 8.

There is nothing of importance to add to the descriptions and figures of the pedicellariæ, etc., given by de Meijere (1904) and Döderlein (1906), as the Hawaiian specimens before us agree in all essentials with those collected by the “Siboga” and “Valdivia.” The *stout tridentate* pedicellariæ, however, occur in only a very few individuals.

One of the specimens from Station 3839 was deformed by the presence of five parasitic gasteropods (Stylifer?) on or near the abactinal system. The hypertrophy of some of the genital and ocular plates (Pl. 58, fig. 8) is very marked, and with this is associated a notable increase in the number of slender spines upon those plates, which are further remarkable for their very light (nearly white) color (Pl. 58, fig. 7).

This species was taken by the “Albatross” at the following stations:

Station 3817. Off Diamond Head, Oahu, Hawaiian Islands. Bott. temp. 73.5°. ? 320 fathoms. Crs. lav. co. s. sh.

Station 3818. Off Diamond Head, Oahu, H. I. Bott. temp. 44.3°. 293–295 fathoms. Fne. co. s. bk. sp.

Station 3836. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 48°. 238–255 fathoms. Br. gy. m. s.

Station 3839. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 46.3°. 259–266 fathoms. Lt. br. m. s.

Station 3865. Off Mokuhooniki Islet, Pailolo Channel, H. I. Bott. temp. 44.8°–45°. 256–283 fathoms. Fne. vol. s. r.

Station 3914. Off Diamond Head, Oahu, H. I. 289–292 fathoms. Gy. s. m.

Station 3918. Off Diamond Head, Oahu, H. I. Bott. temp. 44.5°. 257–294 fathoms. Wh. s. m.

Station 3920. Off Diamond Head, Oahu, Hawaiian Islands. Bott. temp. 44.6°. 265–280 fathoms. Gy. s. br. sh.

Station 4096. Off Mokuhooniki Islet, Pailolo Channel, H. I. Bott. temp. 45.3°. 272–286 fathoms. Fne. gy. s.

Station 4097. Off Mokuhooniki Islet, Pailolo Channel, H. I. Bott. temp. 44.2°. 286 fathoms. Fne. gy. s.

Station 4105. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 43.8°. 314–335 fathoms. Fne. co. s. for.

Station 4107. Off Lae-o Ka Laau Light, Molokai, H. I. Bott. temp. 41.6°. 350–355 fathoms. Co. s. for.

Station 4116. Off Kahuku Point, Oahu, H. I. Bott. temp. 48.8°. 241–282 fathoms. Co. s. for.

Station 4122. Off Barber's Point Light, Oahu, H. I. Bott. temp. 64.6°. 192–352 fathoms. Crs. co. s. sh.

Station 4178.(?) Off Kawahioa Point, Niihau, H. I. 319–378 fathoms. Co. s. r. p.

Bathymetrical range, 192–378 fathoms, but averaging under 300 fathoms. Extremes of temperature, 48.8°–41.6°; average temperature, 44.7°.<sup>1</sup> One hundred and forty-nine specimens.

### *Aspidodiadema tonsum* A. Ag.

*Aspidodiadema tonsum* A. Agassiz, 1879. Proc. Amer. Acad., XIV, p. 199.

Plate 50, figs. 3–5.

The pedicellariæ of this species show greater diversity of form than in any other Echinoid we have examined. In the specimens collected by the "Siboga," de Meijere found slender tridentate (of two kinds), ophicephalous and triphyllous pedicellariæ, while Mortensen found stout tridentate also in the specimens which he examined. The latter speaks of two kinds of ophicephalous pedicellariæ, one with, the other without, glands on the stalk; we are inclined to think that this difference is due to the condition of the glands, whether full or recently discharged, and not to their actual presence or absence. We have found all of the forms of pedicellariæ, described and

<sup>1</sup> The temperatures of Stations 3817 and 4122 are obviously wrong; they should probably read 43.8° and 42.3°, as shown by Stations 3815 and 4123, which are immediately adjoining and at essentially the same depth. By the same reasoning, the temperatures for Stations 3914 and 4178 may be stated as 46° and 42° respectively. In estimating the average temperature these corrected figures have been used.



figured by de Meijere and Mortensen, and in addition two other varieties. A very careful examination of a specimen from Station 5079 revealed no less than *seven* easily distinguishable kinds. The pedicellariæ of this species may therefore be grouped as follows:

The *slender tridentate* are fairly common all over the test. The valves are about one millimeter long, with straight margins and rounded tips. The length of the blade varies proportionally as well as actually, but these pedicellariæ are always easily recognized.

The *stout tridentate* are often common, sometimes rare, and occasionally wholly wanting. They occur mainly near the abactinal system. The valves are comparatively short, usually under a millimeter long, but very broad in proportion, the width about 80 per cent of the length. The margins are scarcely sinuate and the tip is blunt, sometimes truncate, sometimes bent inward as a broad, flat tooth. The blade is nearly filled with a calcareous network.

The *form b* is very different, and is very rare. The few specimens we found were near the abactinal system. The valves (Pl. 50, fig. 3) are rather more than a millimeter long, about half as wide, rather flat, and broadly rounded at the tip. There is a well-developed network in the blade and no articular loop.

The *form c*, which is quite rare and frequently wanting, is closely allied, though we do not find intermediate stages. The valves (Pl. 50, fig. 4) are about .50 mm. long, with the blade about equal to the basal part. The tip may be bluntly pointed (as in our figure) or more truncate (as shown by de Meijere), while a small articular loop is usually present at the base.

The *ophicephalous* pedicellariæ are not very common, and occur mainly on the interambulacra. They have three small valves, each with an articular loop, and are broadly rounded at the tip.

The *triphyllous* pedicellariæ are common everywhere. The valves are rather slender, with round tips, as figured by de Meijere.

The *broad triphyllous* are rare, and are at once distinguished by the flat, truncate, almost square-cut tips (Pl. 50, fig. 5), which are twice as broad as the base. We found none intermediate between these and the common form.

The calcareous particles in the pedicels commonly have the ends drawn out and imperforate as figured by de Meijere, but narrow, irregular, perforated plates also occur. The sphaeridia show no characteristic features. This species was taken by the "Albatross" at the following stations:



Station 4980. Between Kobe and Yokohama, Japan. Bott. temp. 39°. 507 fathoms. Br. m. fne. s. for.

Station 5078. Off Omai Saki Light, Japan. Bott. temp. 38.9°. 475-514 fathoms. Fne. gy. s. glob.

Station 5079. Off Omai Saki Light, Japan. Bott. temp. 39.1°. 475-505 fathoms. P.

Station 5080. Off Omai Saki Light, Japan. Bott. temp. 38.7°. 505 fathoms. Fne. gy. s. glob.

Bathymetrical range, 475-514 fathoms. Extremes of temperature, 39.1°-38.7°. Fifteen specimens.

#### DERMATODIADEMA.

A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 76.

Type-species, *Dermatodiadema globulosum* A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 76.

The attempt of Pomel (1883) to divide *Aspidodiadema* into two genera, without having any specimens before him, has led to a little confusion in regard to the generic name for this group, but there seems to be general agreement now that the name *Plesiadiadema* Pomel is quite unusable. This genus contains six species, which are distinguishable from each other with more or less difficulty. One of them, *antillarum* A. Ag., is characteristic of the West Indian region, where it occurs at depths of 157-1589 fathoms; it was also taken south of the Canary Islands, by the "Valdivia," in 1389 fathoms. Two species, *horridum* and *globulosum*, A. Ag., are known only from the Panamic region, at depths of 902-1772 fathoms. The "Valdivia" collected a species very near *globulosum* in the Indian Ocean at a depth of 1622 fathoms, which Döderlein (1901) has named *molle*, and a second very well characterized species, *indicum* Död., near Sumatra, in 261 fathoms. The latter was taken by the "Siboga" also, in the Java Sea at 289, and in the Banda Sea at 113 fathoms. The "Siboga" took a second species, south of Celebes in 643 fathoms, which de Meijere (1904) has called *amphigymnum*. The three specimens were obviously immature, and we fail to find any character by which they could be distinguished from *horridum* of the same size; the apparent difference in the anal system is neither sufficiently marked nor constant to warrant their separation. The sixth species, which seems to us valid, is *microtuberculatum* A. Ag., taken by the "Challenger" in the southern Atlantic and Pacific Oceans, at depths of from 2025 to 2225

fathoms. These six species are so nearly related that they can be distinguished only when all their characters are taken into account. We find that the number of coronal plates and of ambulacral plates are important features, while the relative size of the abactinal system, the number and arrangement of the anal plates, the distribution of miliary spines and tubercles, and even the pedicellariæ, variable as they are, afford characters which must not be overlooked. Not having had a specimen of *molle* for comparison, we find it difficult to make the distinction between it and *globulosum* tangible, for Döderlein's figures are too indistinct to enable us to determine whether apparent differences in the ambulacral tubercles and the actinostome are real or not. We have been obliged, therefore, to be content with the rather marked differences in the pedicellariæ of these two species.

- Coronal plates numerous, 10-12; abactinal system small, about  $\frac{1}{2}$  h. d.; size large, 23-34 mm. h. d. . . . . *indicum*.
- Coronal plates fewer, 6-9; abactinal system larger, usually about  $\frac{2}{3}$  h. d.
- Anal system with 5-8 large plates around anus; other anal plates small and few, or wanting; vertical diameter of test, .65-.85 h. d.; ambulacra broad, usually exceeding .15 h. d.
- Pedicellariæ valves long and slender (stout tridentate valves about 1.5 mm. long, the width little more than half length; slender tridentate valves about 1.6 mm., perfectly straight and not widened at tip; triphyllous valves about .50 mm.) *globulosum*.
- Pedicellariæ valves shorter and stouter (stout tridentate valves about 1 mm. long, the width  $\frac{2}{3}$  of length; slender tridentate valves about 1.8 mm., expanded at tip and slightly curved; triphyllous valves about .33 mm.) . . . . . *molle*.
- Anal system with more or less numerous plates, chiefly of small size, those around anus seldom conspicuously bigger; vertical diameter of test usually under .70 h. d., but may be .80; ambulacra not so broad, usually under .15 h. d.
- Ambulacral plates numerous (5-6 to each of largest interambulacral); buccal plates with spines; valves of slender tridentate pedicellariæ slightly curved, meeting only near tip *microtuberculatum*.
- Ambulacral plates fewer (3-4 to each of largest interambulacral); buccal plates commonly without spines, though rarely in large specimens one or two may be present on each plate; valves of slender tridentate pedicellariæ straight, meeting for most of their length.
- Size large, up to 20 mm. h. d.; ambulacra with 2-4 tubercles on each plate, none conspicuously larger than the others . . . . . *horridum*.
- Size small, up to 13 mm. h. d., but rarely exceeding 10; ambulacra with 1-3 tubercles on each plate, 1 tubercle on every second or third plate noticeably larger than the others . . . . . *antillarum*.

**Dermatodiadema globulosum** A. Ag.

**Dermatodiadema globulosum** A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 76.  
1904, Panamic Deep Sea Echini, Pl. 24, figs. 1-3.

Plate 50, figs. 6-10.

This species has not yet been taken outside of the Panamic region, but we include it here in order to describe and figure the pedicellariæ.

The *slender tridentate* pedicellariæ are common. In the largest ones the valves (Pl. 50, fig. 7) are remarkably long (about 1.65 mm.) and narrow, with nearly straight margins, and meet each other for nearly their entire length. Smaller ones have the valves from .50 to 1.50 mm. long and not essentially different in form.

The *stout tridentate* are unfortunately rare, for they are very characteristic. The valves (Pl. 50, fig. 6) are about 1.5 mm. long, with the base about .90 mm. broad, and the tip rounded. The blade is filled with a coarse network and the margins are decidedly sinuate.

The *ophicephalous* are not very common. The valves (Pl. 50, fig. 9) are very small, only .20 mm. in length, and are broadly rounded at the tip.

The *triphyllous* are common everywhere and appear to intergrade with the slender tridentate. The valves (Pl. 50, fig. 8) are remarkably long (up to .50 mm.) and have the cover-plate deeply cleft.

The spicules in the pedicels have the ends usually drawn out and imperforate as in *tonsum*, but sometimes flat and perforated.

The sphæridia (Pl. 50, fig. 10) are large, somewhat longer than thick.

**Dermatodiadema horridum** A. Ag.

**Dermatodiadema horridum** A. Agassiz, 1898. Bull. M. C. Z., XXXII, p. 76.  
1904, Panamic Deep Sea Echini, Pl. 24, figs. 4-12.

Plate 50, figs. 11-15.

We include this species also for the sake of the pedicellariæ, which appear to be very easily distinguished from those of *globulosum*; so far as our limited material of the latter permits us to speak, we should say the differences are very constant.

The *slender tridentate* are fairly common. The valves (Pl. 50, fig. 12) rarely exceed 1 mm. in length, and the blade is relatively broader and flatter than in *globulosum*.

The *stout tridentate* are small, infrequent, and very characteristic. The valves (Pl. 50, fig. 11) are only about .60 mm. long, but they are over .40 mm. broad and are noticeably deep. The blade is full of a calcareous network and the tip is rounded or bluntly pointed. They are thus much more like the ordinary form in *A. tonsum* than they are like those of *D. globulosum*.

The *ophicephalous* pedicellariæ have the valves (Pl. 50, fig. 14) a trifle larger and distinctly more pointed than in *globulosum*.

The *triphyllous* have the valves (Pl. 50, fig. 13) relatively shorter and broader than those of *globulosum*, and the cover-plate is not so deeply cleft.

The spicules in the pedicels do not appear to have the ends drawn out and imperforate as in *globulosum*, but are narrow, irregular, perforated plates.

The sphæridia are not peculiar.

### DIADEMATIDÆ Peters.

#### THE PEDICELLARIÆ AND OTHER STRUCTURAL CHARACTERS.

Plates 44, figs. 5, 6 ; 50, figs. 16-21 ; 51.

The Diadematidæ show great diversity in the form of the pedicellariæ and the structure of these organs afford useful characters for the distinctions to be made between genera and species; and yet no very great reliance can be placed on them, because of the frequent absence of a characteristic form and the intergradations shown by the same kind of pedicellariæ in closely related species. As nearly all of the known species have been carefully examined by Mortensen, who has described and figured the pedicellariæ and calcareous spicules in detail (1904), we have confined our figures to one or two species not accessible to him and to the new species we have been called on to describe. No less than *seven* different sorts of pedicellariæ occur in this family, two kinds of tridentate, three kinds of ophicephalous, one triphyllous, and one globiferous. These are never all found in a single specimen, and usually only three or four kinds occur. The globiferous pedicellariæ are found only in *Centrostephanus*, in which genus they are common and sometimes very abundant. In young individuals of the other genera only small tridentate pedicellariæ, usually with some triphyllous and ophicephalous, are commonly found, the large tridentate appearing only with maturity. In some specimens of *Diadema* and *Chætodiadema* pedicellariæ are infrequent and the tridentate are very rare or wholly wanting. In *Leptodiadema* we have failed to find any pedicellariæ whatever.



The *slender tridentate* pedicellariæ (Pl. 51, figs. 3, 12) are commonly present on all parts of the test, but are often infrequent and may be wholly wanting, especially in young individuals. The heads are from .30 to 3 mm. long, and the neck and stalk show an equally great diversity. The head is usually shorter than the stalk, and the latter may be many times as long, but when the head is greatly elongated the stalk may be actually shorter. The neck is longest when the head is shortest, and is so short when the head is very long that it is virtually absent. The valves (Pls. 50, fig. 16; 51, fig. 1) of which there are commonly three but sometimes four, are straight or very little curved, usually compressed, especially at the base of the blade, but often more or less flattened, and the margins are coarsely dentate, becoming more finely serrate near tip. The valves are 3-6 times as long as the width of the basal part, or 6-15 times as long as the width of the blade. There is usually, but not always, a calcareous network more or less developed in the basal half of the blade, and it sometimes extends nearly to the tip.

The *stout tridentate* pedicellariæ (Pl. 51, figs. 4, 13) which are found scattered on the test in varying abundance and are often wholly wanting, when fully developed are strikingly different from the slender tridentate, but it is not possible to draw a sharp line between them, for they seem to intergrade, particularly in the genus *Diadema*, where one species has only slender tridentate and another has only stout tridentate, and others have forms which might be called by either name. The stout tridentate do not show as great a diversity of size as the slender ones, for the head is rarely less than .50 mm., and seldom exceeds 1.50 mm. There is little or no neck and the stalk is usually about as long as the head, though it may be shorter, or in other cases very much longer. The valves are usually decidedly curved and meet only at or near the tip. The margins are coarsely dentate or serrate for a part or all of their length. The length of the valve is only 2-4 times the width of the basal part, and only 3-4 times the width of the widest part of the plate, which is commonly near the tip. There is usually little or no calcareous network in the blade, but it may be very largely developed.

The *non-glandular opificephalous* pedicellariæ (Pl. 51, figs. 5, 14) are very variable in their occurrence, as they are frequently rare and often entirely wanting. When present, they are more likely to be found actinally than abactinally. The head is from .20 to .65 mm. long, while the stalk is 3-5 times that length; there is no neck. The valves are usually provided with



an articular loop, which differs greatly in size in the three, and may be wholly wanting in one. The blade may be sinuate, coarsely dentate, serrate, or nearly smooth on the margin.

The *glandular ophicephalous* pedicellariæ (Pl. 51, fig. 6) do not differ in any essential particular from the non-glandular save in the presence of three conspicuous glands on the stalk. It is quite possible that this difference is due to the stage of development of the pedicellaria, or even that it is apparent rather than real, the difference in appearance being due to the condition of the glands.

The *claviform ophicephalous* pedicellariæ appear to be simply a degradational form of the glandular ophicephalous, in which the glands seem to be developed at the expense of the valves, the latter becoming very small or more often entirely wanting. Such pedicellariæ are very common in the Diadematidæ, especially on the actinal side of the test.

The *triphyllous* pedicellariæ (Pl. 51, figs. 7, 15) are generally common, scattered all over the test, but in some cases are rather rare. The heads are small, only .20–.40 mm. long, and are attached to the very slender stalk by a long neck. The valves (Pl. 50, fig. 18) are flat and more or less leaf-shaped, sometimes narrowed and rounded at the tip, but more commonly truncate or square-cut, and in some cases widest there. No cover-plate is present; Mortensen (1904) describes and figures a cover-plate on the valve of the triphyllous pedicellariæ in *Micropyga*, but there is none in the specimens we have examined, and if it occurs, it must be quite unusual, and not the normal condition.

The *globiferous* pedicellariæ (Pl. 51, figs. 8, 16) are very different from any of the preceding, and are characteristic of the genus *Centrostephanus*. They are conspicuous because of the glands, which not only enclose and may even entirely conceal the valves, but which may also occur on the upper part of the stalk. There is no neck, but the stalk is 2–8 times as long as the head. The valves (Pl. 51, figs. 9, 10, 18, 19) are small, rarely exceeding .45 mm. in length. The basal part is wide, but the blade is abruptly narrowed and at the tip is provided with 4–6 very long and conspicuous teeth. The blade may be shorter than the basal part, and quite evidently hollowed or concave on the inner side, or it may exceed the basal part and be nearly cylindrical, hardly more than flattened on its inner face. The glands vary greatly in their development in different examples. They are sometimes scarcely evident on the stalk but very conspicuous on the valves (Pl. 51,

fig. 16), while at other times they are very large on the stalk but hardly noticeable on the valves. As a general rule one may say that if they are conspicuous on the valves, they will be small on the stalk, and vice versa. The stalk is greatly expanded and more or less concave at the top (Pl. 51, fig. 20).

In all pedicellariæ in this family the stalk consists of a calcareous rod more or less pitted or fenestrated, at least at the enlarged ends. In its simplest and slenderest condition the rod is nearly smooth and cylindrical for the great part of its length, but is more or less abruptly and conspicuously enlarged both at the base and at the top; the enlarged portions are rough, rather distinctly ridged, with cross-bars and pits or openings between the ridges. In other cases the rod is rough with projections, and it may be somewhat flattened and regularly fenestrated in such a way as to appear ladder-like, as though it were made up of two rods united by cross-pieces. Where still more developed the rod is much thicker and is ridged for its whole length with cross-bars, perforations, or pits in between the ridges, and the enlargement of the base and top are relatively small. In its extreme development the stalk has eight or more ridges, and may appear as though made up of that number of rods, closely united by cross-bars, particularly at the two ends. In *Micropyga* the component parts of the stalk are very slender, and the connections between them few and widely separated; such a stalk is best described as made up of numerous calcareous threads, closely united at the ends but only loosely and irregularly connected with each other elsewhere. While at first sight such a stalk appears quite different from that found in other *Diadematidæ*, the difference is, after all, in degree rather than in kind.

The sphæridia (Pl. 50, fig. 20) are more or less ellipsoidal, rarely globular bodies, attached to the surface of the test and seldom sunken in depressions or pits of any kind. They are very small (.15-.30 mm. long), and are provided with short stalks which connect them with minute tubercles on the plates. They are confined to the ambulacra and are generally rather numerous, from 3 to 12, or even more, occurring in each ambulacrum. They are most common on the actinal surface, especially near the peristome, but in some cases they occur only near the ambitus, and in others they are found all along the ambulacrum, from peristome to ocular plate. They most commonly occur near one of the large tubercles, and usually at its outer side, so that they frequently form a vertical series between the large tubercles

and the poriferous zone. In life, they are probably more or less pendent; but in preserved, and especially dried specimens, they are often quite erect.

The calcareous particles of the Diadematidæ are quite characteristic in that they are fundamentally triradiate, and in their simplest condition they exhibit this form very prettily. Such spicules have three branches of equal length, equally distant from each other, perfectly straight, smooth, and pointed; they are to be found chiefly near the tips of the pedicels, and most commonly on the abactinal surface. Usually, however, the branches are not equal, nor are they straight, and they often have subordinate branches growing out from them (Pl. 50, fig. 21). As these branches become more numerous (Pl. 51, fig. 11), they tend to coalesce and make small, irregular plates with few perforations (Pl. 50, fig. 19); these occur in the lower part of the pedicels, or in those of the actinal surface, or sometimes in the gills. These plates may continue their growth in either of two different ways: they may elongate, but remain narrow, increase in thickness, and decrease the diameter of the perforations, and thus become such supporting plates as occur in the pedicels, especially of the actinal surface, of many individuals; or they may increase in diameter irregularly in all directions, remaining thin and with large perforations, and thus become the fenestrated plates which occur commonly in the gills, and sometimes in the pedicels, of many species. These plates sometimes grow to a large size, in the basal part of the gills becoming large enough to be seen with the unaided eye. In *Micropyga*, one branch of the fundamental triradiate spicule becomes greatly elongated, and either forms the handle of the characteristic anchor-shaped particles found in the pedicels of that genus, or becomes a rod, expanded and fenestrated at each end and in the middle; these rods often show their triradiate origin plainly, and not infrequently develop into irregular perforated plates. As age and condition appear to affect profoundly the size and number of the calcareous particles, we fail to find in them any satisfactorily constant generic or specific characters, except, of course, in *Micropyga*.

The arrangement of the internal organs in *Chætodiadema* (Pl. 44, figs. 5, 6) is illustrative of the whole family; for a careful examination of specimens of *Diadema*, *Echinothrix*, *Astropyga*, and *Micropyga* reveals no important character in which these genera differ from each other. The reproductive organs are very dense masses of short tubules, which occupy a greater or less proportion of each interambulacrum according to their maturity. The alimentary canal is remarkable for its very great development, its total

length exceeding  $2\frac{1}{2}$  times the external circumference of the test. The oesophagus is remarkably long, first bending backwards above the lantern and then turning to the left and running forwards to the anterior ambulacrum, where it enlarges abruptly to form the stomach-intestine. The first or lower coil of the intestine, which runs from left to right (*i. e.*, contrary to the hands of a clock), is arranged in a double fold in each ambulacrum except in the anterior one, where only the right-hand fold occurs, the other being replaced by the abrupt, upward and backward turn of the canal. The second or upper coil, running back from right to left above the other, is not so extensively folded, but is yet greatly lengthened by a very deep loop in each interambulacrum. The loop in the left anterior interambulacrum is the smallest, and passes by gradual change into the rectum, which is straight and not noticeably enlarged. The two intestinal coils fit into each other in such a manner that the loops of the upper reach down into the actinal half of the test and lie snugly between the double folds of the lower. The two are united so extensively with each other and with the test by mesenteries and strands of connective tissue that they are held firmly in place, and can only be separated, without injury, by very careful dissection.

#### THE GENERA AND SPECIES OF RECENT DIADEMATIDÆ.

There is still much room for difference of opinion as to the limits of this family when the fossil forms are taken into account, but so far as recent species are concerned, the only point which causes discussion is whether *Micropyga* should be regarded as one of the family or not. Mortensen (1904) established a separate family for *Micropyga*, and Döderlein (1906) has followed him in this arrangement. We have given very careful attention to the matter, and have made extensive comparisons of the internal anatomy of *Micropyga*, as well as its external features, with other genera of Diadematiidæ, and we find no sufficient reason for removing the genus from that family. The characters upon which the family Micropygidae are based, are stated by Mortensen (1904, p. 45) as follows: "This family is characterized above all by its anchor-shaped spicules, further by wanting ophicephalous pedicellariæ, either in the form of true ophicephalous or of claviform ones; the triphyllous pedicellariæ are finely serrate in the outer edge, and the stalk of the pedicellariæ consists of several slender rods, almost not united, except at the ends. The tubercles are perforate,



non-crenulated. The biserial arrangement of the pores and the deep actinal cuts may probably not be family characters; that the extraordinary development of the tube-feet in *M. tuberculata* is no character of high order is proved by the fact that in *M. violacea* these tube-feet are simple." If we examine these characters with a little care we find that only the first one is remarkable, for Döderlein (1906) has already noted the occasional presence of ophicephalous and claviform pedicellariæ, while the extremely minute serration of the end of the triphyllous valves is surely not of family importance. The structure of the stalk of the pedicellariæ, while very characteristic, differs only in degree and not in kind from what we find in the other Diadematidæ; even if essentially different, Dr. Mortensen could hardly consider it a family character, for a similar difference in the Echinothuridæ, he regards as a characteristic of his genus *Kamptosoma*. Non-crenulate tubercles are not unknown in the Diadematidæ; Dr. Mortensen gives them as one of the characters of his genus *Lissodiadema*. The anchor-shaped spicules are, then, the one characteristic feature of the Micropygidæ; we are inclined to add also the remarkable biserial arrangement of the pores, though Dr. Mortensen says that is "probably not" a family character. One feature of the internal anatomy is very striking and seems to us worthy to be mentioned with these two; namely, the ends of the compass-rods of the "lantern" are perfectly simple and similar, the outer end not being widened and more or less bifurcate as it is in other echini. Against these three notable peculiarities of *Micropyga*, we have to set the important resemblances to the Diadematidæ, which are present. The arrangement of the alimentary canal and the structure of the "lantern" and teeth are essentially as in *Echinothrix* and *Astropyga*. The form and structure of the test and the abactinal and anal systems are distinctly Diadematoid. The composition of the compound plates of the ambulacra is, in spite of the biserial arrangement of the pores, surprisingly like *Diadema*, more so indeed than we find to be the case in *Astropyga*.<sup>1</sup>

<sup>1</sup> Dr. Mortensen (1904, p. 42) makes a curious slip in regard to the value of the characters shown by the ambulacra, for he says: "I can only admit three different types, viz.: the Cidaroid type, with simple primaries which do not combine to form compound plates, the Diadematoid type in which the adoral primary plate is a small plate, the following one being the largest, and the Echinoid type in which the adoral component is the largest and never a demi-plate, the following being smaller. But these features do not present generic or family characters; they are of higher value. All the families of Ectobranchiata may be arranged in three groups, namely, with simple, or diadematoid or echinoid ambulacra; these are then characters of orders." If this be true we are wrong in placing *Tetrapygyus* in the Arbaciadæ, for Duncan and Sladen (1885) long since showed that its ambulacra are "echinoid" and not "diadematoid" as are those of the Arbaciadæ. Are we to presume that Dr. Mortensen will establish a family "Tetrapygidæ" under his "Tribus 4. Echinina," for this aberrant genus?



Finally the hollow, verticillate spines and perforate tubercles show a close relationship to the Diadematidæ. In view of all these facts, we feel obliged to reject the family Micropygidæ, since its recognition seems to us to involve a most unnatural separation of Micropyga from its nearest allies.

In addition to Micropyga, we find it desirable to recognize eight genera of recent Diadematidæ, of which Diadema, Echinothrix, Centrostephanus, and Astropyga are old and well-established. There can be no question, either, as to the validity of Chætodiadema, but Lissodiadema and Leptodiadema are both based on very small specimens and their real status is not perfectly clear. As the eighth genus, we wish to establish Eremopyga, based on *Astropyga denudata* de Meijere, from the Dutch East Indies. This handsome "Siboga" echinoid has hollow spines, few primary tubercles in the interambulacra, a primary tubercle on each ambulacral plate (at least near the ambitus) and narrow poriferous zones with the arcs of pores in a nearly vertical series; while *Astropyga* has solid spines, many primary tubercles in the interambulacra, a primary tubercle only on every second or third ambulacral plate (even at the ambitus), and broad poriferous zones with the arcs of pores decidedly oblique. These differences appear to us to be too important to warrant placing *denudata* in *Astropyga*.

The genera we recognize are distinguished from each other largely by the structure of the primary spines and the distribution of the primary tubercles, but the form and structure of the test, the presence of spines on the buccal plates, the width of the poriferous zones, the crenulation of the tubercles, the size of the actinostome, the structure of the pedicellariæ and even the calcareous particles in the pedicels, furnish more or less important and usable characters. The following table will make the differences clear.

Primary spines of interambulacra rough with minute teeth, which are arranged either in whorls or in crowded longitudinal series.

Normal primary spines hollow for the greater part of their length.

Test moderately thick, more or less flattened, with vertical diameter about half horizontal, always exceeding .40 h. d., sometimes over .60.

Buccal plates with few or no spines; no globiferous pedicellariæ.

Ambulacra with few or no secondary tubercles abactinally and narrower there than at ambitus; ambulacral primary spines not essentially different from those of interambulacra . . . . . *Diadema*.

- Ambulacra with numerous secondary tubercles abactinally and distinctly wider there than at ambitus; ambulacral spines filiform, smooth except near tip . . . *Echinothrix*.
- Buccal plates with numerous spines; globiferous pedicellariae present . . . . . *Centrostephanus*.
- Test thin, much flattened, with vertical diameter about one-third horizontal and never exceeding .40 h. d.
- Pores distinctly biserial; anchor-shaped spicules in pedicels . . . . . *Micropyga*.
- Pores uniserial or nearly so; no anchor-shaped spicules in pedicels . . . . . *Eremopyga*.
- Normal primary spines with central cavity so filled by a calcareous network that under low magnification they appear solid in cross-section.
- Actinal surface with normal primary tubercles; poriferous zones becoming wider at peristome; primary tubercles in ambulacra, near ambitus, only on every second or third plate; actinostome, .25-.35 h. d. . . . . *Astropyga*.
- Actinal surface with tubercles tending to become small and densely crowded near peristome; poriferous zones at peristome reduced to a single series of widely separated pairs of pores; primary tubercles on each ambulacral plate, at least near ambitus; actinostome very small, only .15-.25 h. d. . . . *Chaetodiadema*.
- Primary spines of interambulacra nearly or quite smooth, even under high magnification.
- Primary tubercles non-crenulate; each coronal plate at ambitus with 3 primary and 8 or 9 secondary tubercles . . . . . *Lissodiadema*.
- Primary tubercles finely crenulate; each coronal plate at ambitus with not more than 2 primary and 4 or 5 secondary tubercles . . . *Leptodiadema*.

DIADEMA.

Gray, 1825. Ann. Phil., p. 4.

Type-species, *Echinometra setosa*, Leske, 1778. Add. Klein, p. 36.

Few genera of Echini afford as much difficulty as does this one in the way of distinguishing its component species, for while typical examples from widely separated localities look quite different and seem to be readily distinguishable, as soon as one attempts to state the differences it is found that they are remarkably intangible. For example, the olive cast of color of typical Hawaiian specimens is very different from the reddish tinge of certain examples from Zanzibar, and neither is at all like the deep purplish-black of West Indian specimens. But when large series of specimens are examined these differences of color are found to be very unreliable, and it seems clear that no reliance can be placed on color for separating the species.

The same is true to a greater or less degree of all the other characters by which it is customary to distinguish species, and we are finally driven to lay weight on characters which seem trivial and of doubtful value. There seems to be no doubt that the type-species (*setosum*) can always be distinguished when mature; it ranges from Zanzibar to Tahiti and perhaps even to Japan. But other Diademas, which are certainly not *setosum*, occur throughout the Indo-Pacific region, as well as in the West Indies, and on both coasts of tropical America. Do these all represent a single species, or are there characteristic forms in each of these widely separated areas? After careful study of large series of specimens, it has seemed better to us to try and distinguish five species than to mass all this material together under one name. Accordingly we distinguish *antillarum* Phil. from the tropical Atlantic, *mexicanum* A. Ag. from the West Coast of tropical America and the Galapagos Islands, *paucispinum* A. Ag. from the Hawaiian Islands, *globulosum* A. Ag. (including *nudum* A. Ag.) from the Gilbert and Society Islands and Hong Kong, and *Savignyi* Mich. from the whole Indo-Pacific region, Zanzibar to Easter Island. All of the species are littoral. The characters by which they are distinguished are the arrangement of the primary tubercles in the interambulacra abactinally, the character of the spines, the size of the abactinal system, the depth of the actinal cuts, and the form of the tridentate pedicellariæ. The following table will show how these features are combined in the six species which we recognize.

Second series of interambulacral primary tubercles begins abactinally on 7th or 8th coronal plate; spines slender, fragile, with 24-32 longitudinal series of teeth; tridentate pedicellariæ slender, with narrow, compressed valves	<i>setosum</i> .
Second series of tubercles begins abactinally on 4th, 5th, or 6th (rarely 7th) coronal plate; spines stouter, with 20-28 longitudinal series of teeth; tridentate pedicellariæ stout, with wide valves which are little or not at all compressed.	
Abactinal system less than half diameter of actinostome.	
Actinal cuts usually deep and narrow; secondary and miliary tubercles rather few actinally; valves of tridentate pedicellariæ rather flat, nearly straight, with apophysis ending in a T . . .	<i>antillarum</i> .
Actinal cuts usually wide and shallow; secondary and miliary tubercles rather numerous actinally; valves of tridentate pedicellariæ slightly compressed at base of blade, wide near tip, curved, with apophysis ending in a Y . . . . .	<i>mexicanum</i> .
Abactinal system more than half diameter of actinostome.	
Abactinal system .50-.55 of diameter of actinostome; second series of tubercles begins on 4th or 5th coronal plate; ambulacra narrow, about $\frac{1}{4}$ of interambulacra; valves of tridentate pedicellariæ somewhat compressed though broad, not narrowed near tip . . .	<i>paucispinum</i> .

Abactinal system about .60 of diameter of actinostome; second series of tubercles begins on 6th (sometimes 5th or 7th) coronal plate; ambulacra wider, sometimes  $\frac{1}{3}$  of interambulacra.

Valves of tridentate pedicellariæ widened near tip, distinctly curved, not very flat; color usually with more or less of a reddish cast . . . . . *Savignyi*.

Valves of tridentate pedicellariæ distinctly narrowed near tip, nearly straight, flat; color usually with an olive cast or nearly uniform black . . . . . *globulosum*.

**Diadema setosum** Gray.

*Echinometra setosa* Leske, 1778. Add. Klein, p. 36.

*Diadema setosa* Gray, 1825. Ann. Phil., X, p. 4.

We have nothing to add to Mortensen's account of this species under the name *saxatile* L. The slender tridentate pedicellariæ are certainly very characteristic when present, but are unfortunately often wanting, particularly in young specimens. Occasionally tridentate pedicellariæ of large size are met with in which the valves are much wider than usual and approach the form of those of *paucispinum*, but as a rule a single glance with a magnifying glass at one of the large tridentate pedicellariæ of a *Diadema* is sufficient to determine whether it is *setosum* or not.

This species was taken by the "Albatross" on the reef of Neiafu, Vavau, Tonga Islands. Dec. 5, 1899. One specimen.

**Diadema mexicanum** A. Ag.

*Diadema mexicanum* A. Agassiz, 1863. Bull. M. C. Z., I, p. 19.

We have but little to add to Mortensen's description of the pedicellariæ of this species, except as regards the large tridentate. The "inward fold" at the tip of the valve which he describes and figures we find to be rather rare in our specimens, but on the other hand there are some details of structure by which these pedicellariæ can be distinguished from those of *antillarum*. The valves are generally quite distinctly curved, wide near the tip and somewhat compressed above the basal part, so that the end of the apophysis is Y-shaped, while in *antillarum* the valves are straighter and flatter and the end of the apophysis is T-shaped. The differences are so slight that we are not inclined to lay much stress upon them, and yet we find they are fairly constant. The pedicels often contain larger and more



numerous perforated plates than we have found in any other species, but this feature is not sufficiently constant to be relied upon for a specific character.

This species was taken by the "Albatross" at Acapulco, Mexico, 1905. Two specimens.

**Diadema paucispinum** A. Ag.

*Diadema paucispinum* A. Agassiz, 1863. Bull. M. C. Z., I, p. 19.

Plate 51, figs. 1, 2.

As Mortensen was unable to examine the pedicellariæ of this species, we have given a figure of a valve of one of the large tridentate, which shows some characteristic features. It is an open question whether these pedicellariæ should be called "slender" or "stout" tridentate, but we have preferred to regard them as "slender," because the valves, though broad, are distinctly compressed and are very straight. Occasionally they approach in form the slender tridentate of *setosum*, but the valves are never sufficiently narrowed to make confusion with that species possible. The margin of the valves is strongly dentate, and the tip is broad and bluntly rounded. The calcareous network in the blade is well developed.

This species was taken by the "Albatross" at the following stations:

Puako Bay, Hawaii, Hawaiian Islands.

Honolulu, Oahu, H. I.

Station 3968. French Frigate Shoal, H. I. 14½–16½ fathoms. Crs. s. co.

Station 4169. Off Modu Manu, H. I. Bott. temp. 78.6°. 21–22 fathoms. Co.

Nine specimens.

**Diadema Savignyi** Mich.

*Diadema Savignyi* Michelin, 1845. Rev. Mag. Zool., p. 15.

It is an interesting fact that the *Diadema* found by the "Albatross" at Easter Island should prove to be of this species, thus extending its known range far to the southeastward. As there is only a single specimen, and that not in good condition, we have only found one or two examples of large tridentate pedicellariæ. These, however, agree sufficiently well with those of *Savignyi* to warrant our calling the specimen by that name, especially since the reddish color, the large abactinal system, and the beginning of the second series of interambulacral tubercles on the sixth coronal plate are fea-



tures that it shares with *Savignyi* and combine to distinguish it from the other members of the genus.

This species was taken by the "Albatross" only at Easter Island. Dec. 21, 1904, littoral, one specimen.

**Diadema globulosum** A. Ag.

*Diadema globulosum* A. Agassiz, 1863. Bull. M. C. Z., I, p. 20.

As pointed out by Mortensen, this species is very near *Savignyi*, and yet the large tridentate pedicellariæ, when fully developed, are so readily distinguished from those of that species that we are inclined to keep them separate. The valves in *globulosum* are remarkably flat and very nearly straight, with the blade broad but becoming distinctly narrower near the tip. The example figured by Mortensen is not quite typical, as this narrowing is not clearly shown. In some cases it is very marked, one might almost call it abrupt; but, unfortunately, it is not always so. Examination of the type-specimen of *D. nudum* A. Ag. from Hong Kong shows that the pedicellariæ are like those of *globulosum*, and there seems to be no good reason why the two should not be united under the latter name, which has four months' priority.

This species was taken by the "Albatross" only on the reef of Papeete, Tahiti, Society Islands. "Albatross" collection. Sept. 29, 1899. One specimen.

**ECHINOTHRIX.**

Peters, 1853. Monatsb. Berlin Akad., p. 484.

Type-species, *Echinus calamaris* Pallas, 1774. Spic. Zool., I, fasc. 10, p. 31.

Typical examples of the two species belonging to this genus are so very different from each other that their confusion seems impossible, but when a large series of specimens of all ages and sizes is examined, the characters which are supposed to separate them prove very inconstant, with the single exception of the structure of the spines. Thus the color is ordinarily very different, *E. diadema* being often uniform black, or with only faint indications of banding with light and dark shades on the spines, while *E. calamaris* is often very light colored, with the interambulacral primaries beautifully annulated and the ambulacral primaries a uniform pale yellowish-green; but young specimens of *diadema* are much lighter and have the spines as distinctly annulated as *calamaris*, while large specimens of the latter are

frequently so dark that their coloration is just like that of *diadema*. Döderlein (1902) has suggested that the two species may be distinguished by the coloration of the primary spines of the ambulacra, which he says are distinctly banded in *diadema* and unicolor in *calamaris*. While this seems to be true in most cases, we have found exceptions in both species, some specimens of *diadema* having the annulations wanting (and they are often very faint), while some specimens of *calamaris* have faint, but still distinct, indications of the bands. As regards the tuberculation of the test, *diadema* rarely has more than three primary tubercles on a coronal plate, while *calamaris* may have five or even six; but unfortunately most specimens of the latter have, like *diadema*, only three, and occasional specimens of *diadema* have four. The difference in the structure of the primary spines seems, however, to be remarkably constant at all ages, and we therefore distinguish the two species by that character. It seems to be true also that the tridentate pedicellariæ are constantly different and furnish an additional specific character.

There are apparently only two species which can be constantly recognized in the genus, both littoral and ranging throughout the Indo-Pacific region from Zanzibar to the Society and Hawaiian Islands. The species *Desorü* Agass. seems to be undoubtedly a form of *calamaris*, probably the fully matured adult; the essential structure of the spines and the pedicellariæ are like *calamaris*, and the differences in the test do not appear to be constant. We distinguish *calamaris* and *diadema* as follows:

Primary spines of interambulacra rather solid, diameter of central cavity much less than $\frac{1}{2}$ diameter of spine; minute teeth covering spine, arranged in crowded longitudinal series and not in distinct whorls; blade of valves of tridentate pedicellariæ widest near middle . . . . .	<i>diadema</i> .
Primary spines of interambulacra fragile, diameter of central cavity more than $\frac{1}{2}$ diameter of spine; minute teeth covering spine, arranged in distinctly separated whorls; blade of valves of tridentate pedicellariæ widest at or near tip . . . . .	<i>calamaris</i> .

### **Echinothrix diadema** Lovén.

**Echinus diadema** Linnæus, 1758. Sys. Nat., p. 664.

**Echinothrix diadema** Lovén, 1887. Ech. desc. by Linn., p. 137.

This species was taken by the "Albatross" at the following stations:

Puako Bay, Hawaii, Hawaiian Islands.

Honolulu, Oahu, H. I.

Papeete, Tahiti, Society Islands. Sept. 29 and Nov. 14, 1899. Reef.

Thirty-one specimens.

**Echinothrix calamaris** A. Ag.**Echinus calamaris** Pallas, 1774. Spic. Zool., I, fasc. 10, p. 31.**Echinothrix calamaris** A. Agassiz, 1872. Rev. Echl., Pt. I, p. 119.

This species was taken by the "Albatross" at the following stations :

Puako Bay, Hawaii, Hawaiian Islands.

Station 4033. Penguin Bank, S. coast of Oahu, H. I. 28-29 fathoms.

Fne. co. s. for.

Two specimens.

**CENTROSTEPHANUS.**

Peters, 1855. Denk. Akad. Berlin für 1854, p. 109.

Type-species, *Diadema longispina* Philippi, 1845. Arch. f. Naturg. XI (1), p. 354.

The species of this genus are remarkable not only for the fact that they are so easily recognized, — synonyms are almost unknown among them, — but also for the presence of peculiar glandular, globiferous pedicellariæ, and for their geographical distribution. Unlike all the other genera of Diadematidæ, *Centrostephanus* is unknown from the Indo-Pacific region, nor does it occur in the West Indies, and yet the four species are widely separated from each other. One species, *longispinus* Phil., occurs in the Mediterranean and eastern Atlantic, a second, *coronatus* Verr., is found on the west coast of Mexico, a third, *asteriscus* A. Ag. and Cl., is known only from the Hawaiian Islands, while the fourth, *Rodgersii* A. Ag., inhabits the coasts of Australia, Lord Howe Island, and Tasmania. All are strictly littoral. These species are easily distinguished from each other by the coloration, which appears to be unusually constant. They may be recognized by the following characters :

Primary spines unicolor, deep reddish-purple (lighter in very small specimens, and with faint indications of bands); size large, up to 100 mm.

h. d. or more . . . . . *Rodgersii*.

Primary spines banded with two colors or shades; size small, rarely exceeding 40 mm. h. d.

No whitish markings on abactinal part of test; spines banded with light and dark reddish or reddish-brown . . . . . *coronatus*.

Conspicuous whitish lines present on abactinal part of test; spines banded in two colors.

Whitish lines present in middle of each ambulacrum and interambulacrum, and along margin of each ambulacrum, abactinally; spines banded with light yellowish-green and purplish . . . . . *longispinus*.

Whitish lines run only from centre of anal system to upper end of each ambulacrum, thus forming an abactinal star; spines banded with deep red and white . . . . . *asteriscus*.

**Centrostephanus coronatus** A. Ag.

*Echinodiadema coronata* Verrill, 1867. Trans. Conn. Acad., I, p. 295.

*Centrostephanus coronatus* A. Agassiz, 1872. Rev. Ech., Pt. I, p. 97.

## Plate 51, figs. 12-20.

As this is one of the very few species of Diadematidæ, whose pedicellariæ have not been examined by Mortensen, we have given figures of them, since they are very different from those of the other species in the genus.

The *globiferous* pedicellariæ (figs. 16, 17) are very abundant and are strikingly characteristic, because of the conspicuous, nearly globular, deep purple glands on the valves. The latter (figs. 18, 19) are remarkably small, only .12-.18 mm. in length, and decidedly curved. The blade is very short, concave on its inner face, and terminates in 4 very long, sharp teeth. The stalk (fig. 20) is greatly expanded at the tip, which is distinctly concave. The organic covering of the stalk is prettily spotted with pigment cells (figs. 16, 17). At the top of the stalk, glands are often but not always present.

The *slender tridentate* pedicellariæ (fig. 12) are very rare and are found only on the abactinal surface. The valves are a trifle over a millimeter long and the stalk is little longer. The blades are narrow and compressed and are in contact for nearly one-half their length. The margins are irregularly serrate.

The *stout tridentate* pedicellariæ (fig. 13) are common on all parts of the test and vary greatly in size. The valves range from .40 to 1.75 mm. in length. They are decidedly curved, with short wide blades, in contact only at the tip. The margins carry few or no teeth, but the tips are strongly serrate. The stalk scarcely equals the valves in large examples, but may be much longer in small ones.

The *ophicephalous* pedicellariæ (fig. 14) seem to be all of the glandless type. They are abundant everywhere, but especially on the actinal surface. The valves are rather short and blunt, only .30-.40 mm. in length.

The *triphyllous* pedicellariæ (fig. 15) are common, and are noticeable because of the scattered pigment cells which adorn the organic covering of the stalk and the neck. The latter is considerably thicker than the stalk, while the diameter of the head is only a little greater. The valves are only .20-.30 mm. long, and are wider in proportion to their length than in the other species of the genus.



The calcareous particles in the pedicels are distinctly triradiate, and show little or no tendency to become perforated plates.

The sphaeridia are not peculiar.

This species was not collected by the "Albatross."

**Centrostephanus asteriscus** A. Ag. and Cl.

*Centrostephanus asteriscus* A. Agassiz and Clark. Bull. M. C. Z., L, p. 237.

Plates 51, figs. 3-11; 55, figs. 1-6; 58, figs. 1-6.

This very pretty small species is easily distinguished from other members of the genus by the large number of coronal plates and the peculiar abactinal system. In a specimen of 3.5 mm. in diameter there are already eight interambulacral coronal plates and an individual 14 mm. in diameter has thirteen (Pls. 55, figs. 1-3; 58, fig. 6), with fifteen or sixteen ambulacral plates, while in a young specimen of *C. Rodgersii* A. Ag. of 14 mm. there are only nine interambulacral coronal plates, and the large primary tubercles are all placed on the abactinal surface above the ambitus. In *asteriscus* many are at the ambitus and below it. In a specimen of *C. coronatus* Verrill of 14 mm. there are only eight and nine interambulacral plates, and in the abactinal system the genitals are well separated by the oculars which reach the anal system. The latter is covered by fewer and larger plates, more like that of *Rodgersii*. In *Rodgersii* the oculars separate the genitals, but scarcely reach the anal system, which is covered by comparatively few large plates, in great contrast to the very numerous plates covering the anal system of *asteriscus* (Pls. 55, fig. 2; 58, fig. 4). In small specimens of *asteriscus* the small oculars appear to reach the anal system by the extension of a slightly raised white ridge (Pl. 58, fig. 2) running from the median part of each ocular plate and extending to the centre of the anal system, thus forming a conspicuous star on the red abactinal surface. With increasing size the ocular plates are crowded further out by the genitals, which form an independent ring. The genital plates are very uniform in size and shape (heptagonal) and carry three to six distinct miliaries. The madreporic openings are small, forming a narrow band across the promixal part of the right anterior genital (Pl. 55, fig. 2). The genital openings are well marked and placed near the outer edge of the plates.

In all the Pacific species of *Centrostephanus* the radioles are banded with reddish brown upon a lighter shaft; the bands are fewest, darkest, and widest, and are least distinct in *Rodgersii*, in adult specimens of which they



are wholly wanting, and are most numerous in the Californian *coronatus*, which at first glance most resembles *asteriscus*. The colors are much the brightest in *asteriscus*. The radioles of the largest specimen of *asteriscus* (14 mm.) are about one-half longer than the diameter of the test. This specimen is 6.25 mm. high, the abactinal system is 5.5 mm. in diameter, and the actinal, 6 mm. The radioles are marked by widely spaced whorls of very minute sharp spinelets (Pl. 55, figs. 5, 6).

The primary interambulacral tubercles form two rows flanked by a row of indistinct secondaries adjoining the poriferous zone and an irregular double median row along the vertical suture. The secondaries are most prominent about the equatorial zone or ambitus (Pls. 55, figs. 1-3; 58, figs. 4-6).

The primary ambulacral tubercles are much smaller and form two single vertical rows separated on the median line by a few irregularly placed secondaries. At the actinal edge of the ambulacral zone the pairs of pores of the first three plates are more or less crowded together but have their regular arrangement somewhat higher up (Pl. 55, fig. 4). The actinal membrane is covered with five or six rows of narrow elongate plates outside of the five pairs of buccal plates, which are large, forming a connected ring. Between the buccal plates and the teeth there are two or three irregular rows of small rounded plates. The color of the test is light reddish, becoming reddish-white actinally, and the primary radioles are banded with red and whitish; from the end of each ambulacrum a conspicuous white line runs straight to the centre of the anal system, the five lines forming a conspicuous star on the red abactinal surface. This star is well marked in alcoholic specimens, but becomes very faint when they are dried.

The pedicellariæ are abundant, diverse, and very characteristic. The *globiferous* (Pl. 51, fig. 8) are the most striking because of the conspicuous, dark-colored glands which enclose or at least conceal the terminal half of the valves. These pedicellariæ are quite common and occur all over the test and on the actinostome. The heads are about .35-.45 in length and are borne on stalks two or three times as long. Glands are commonly present at the upper end of the stalk, but are never very conspicuous. The valves (Pl. 51, figs. 9, 10) are .30-.40 mm. long and terminate in 5 or 6 long and conspicuous teeth. The blade is nearly cylindrical, except at the expanded tip, and is scarcely at all hollowed, though flattened on its inner surface. The basal part is not so long as the blade, but the apophysis is very high and conspicuous.

The *slender tridentate* pedicellariæ (Pl. 51, fig. 3) are common all over the test. The valves range from .80–2.20 mm. in length and the stalk is usually longer, sometimes two or three times as long. The blade is very narrow, straight, and somewhat compressed, and the margin is coarsely dentate.

The *stout tridentate* pedicellariæ (Pl. 51, fig. 4) are rare and occur on the abactinal half of the test only. The valves are only .60–.70 mm. in length, while the stalk may be two or three times as long. The blades are broad, rather flat, and considerably expanded at the tip, the only point where they are in contact. The margin is irregularly serrate. Although these pedicellariæ are so obviously different from the normal slender tridentate, intermediate forms with the valves only slightly curved are occasionally to be found.

The *glandless ophicephalous* pedicellariæ (Pl. 51, fig. 5) are not uncommon, and are scattered all over the test. The valves are large, wide, and rounded at the tip and may be as much as .60 mm. long. The stalk is several times that length and appears to be entirely without glands.

The *glandular ophicephalous* pedicellariæ (Pl. 51, fig. 6) are common all over the test and especially on the buccal plates. They do not differ essentially from the glandless ones, but the valves are usually smaller and narrower near the tip, and the stalk carries three large and conspicuous glands.

The *triphylous* pedicellariæ (Pl. 51, fig. 7) are rather rare, but occur scattered on the test. They are very small, the heads only about .20 mm. long, the neck a little longer, and the stalk five or six times as long. The valves are rather narrow, the blade little wider than the basal part, but widest above the middle.

The calcareous particles in the pedicels (Plate 51, fig. 11) are rather common. They show their triradiate origin plainly, and rarely form perforated plates.

The sphaeridia are minute, scarcely .25 mm. long, and are elongated ellipsoidal in form, the length nearly equalling twice the width. They are pendent at the outer, lower side of the large ambulacral tubercles and are not placed in depressions. Only a few (4–8) are present in each ambulacrum.

Station 4034. Penguin Bank, S. coast of Oahu, Hawaiian Islands. 14–28 fathoms. Fne. co. s. for.

Station 4066. Off Ka Lae-o Ka Ilio Point, Maui, H. I. Bott. temp. 52.5°. 49–176 fathoms. Rky.

Station 4128. Off Hanamaulu, Kauai, Hawaiian Islands. Bott. temp. 47.8°. 68–253 fathoms. Crs. br. co. s. for.

Station 4161. Off Modu Manu, H. I. Bott. temp. 77.9°. 39–183 fathoms. Co. corln.

Station 4163. Off Modu Manu, H. I. Bott. Temp. 78.1°. 24–40 fathoms. Co.

Bathymetrical range, 14–253 fathoms. Extremes of temperature, 78.1°–47.8°. Five specimens.

### MICROPYGA.

A. Agassiz, 1879. Proc. Am. Acad., XIV, p. 200.

Type-species, *Micropyga tuberculata* A. Agassiz, 1879. Proc. Am. Acad., XIV, p. 200.

Having already discussed the peculiarities of this genus, we need only add here that there seem to be two well-marked species, the “Siboga” having collected a single specimen, which, while a *Micropyga*, is clearly not *tuberculata* A. Ag. To this form, which was taken off Ceram in 512 fms., de Meijere has given the name *violacea*. The “Challenger” species was taken by the “Siboga” at two stations and was also taken once by the “Valdivia,” so that it is now known to range from Sumatra to the Fiji Islands in depths of 100 to 225 fms. (possibly 610 at Fiji). The two species are easily distinguished as follows:

- |   |                      |
|---|----------------------|
| Ambulacra with only 2 columns of primary tubercles; abactinal surface with comparatively few primary tubercles (about 600 in a specimen, 100 mm. h. d.); buccal membrane perfectly bare . . . . . | <i>tuberculata</i> . |
| Ambulacra with 4 columns of primary tubercles; abactinal surface with numerous primary tubercles (about 1100 in a specimen, 84 mm. h. d.); buccal membrane covered with pedicellariæ . . . . .    | <i>violacea</i> .    |

### EREMOPYGA.

Gen. nov.

Type-species, *Astropyga denudata* de Meijere, 1903. Tijdschr. Ned. Dierk. Vereen. (2) VIII, p. 4.

The specimens of this handsome Echinoid, on which de Meijere based his new species of *Astropyga*, were taken by the “Siboga” at three widely separated stations, near Celebes, Flores, and Sumbawa, at depths of 82–152 fms. As already stated, they seem to us to be quite distinct from *Astropyga*, and we have accordingly formed this new genus for them. Mortensen

(1904) suggests that they seem to be near *Chaetodiadema*; while this is true in certain respects, the hollow spines show they are no nearer to that genus than to *Astropyga*.

## ASTROPYGA.

Gray, 1825. Ann. Phil. p. 4.

Type-species, *Cidaris radiata* Leske, 1778. Add. Klein, p. 116.

Since Agassiz in 1846 named *Astropyga pulvinata*, no valid species has been added to this genus, so that we find it necessary to recognize only two. Of these, *radiata* (Leske) occurs throughout the Indo-Pacific region from Zanzibar to Hawaii, while *pulvinata* Agass. is known only from the West Coast of Mexico and Central America. The tuberculation of the actinal side of the test will always distinguish specimens of these two species, but the color is also a useful character. Both are distinctly littoral.

Columns of primary tubercles on actinal surface parallel with ambulacra, so that outermost column (next to ambulacrum) at ambitus, extends to peristome, though the tubercles may become much smaller there; general coloration more or less red or reddish . . . . . *radiata*.

Columns of primary tubercles on actinal surface parallel with midline of interambulacrum, so that outermost 2 columns on each side do not reach peristome; general coloration more or less greenish; no red . . . . . *pulvinata*.

***Astropyga radiata* Gray.**

*Cidaris radiata* Leske, 1778. Add. Klein, p. 116.

*Astropyga radiata* Gray, 1825. Ann. Phil., X, p. 4.

The "Albatross" took a single, young specimen (26 mm. in diameter) of this species at the following station:

Station 3875. Auau Channel, between Maui and Lanai. Bott. temp. 70.8°. 34-65 fathoms. Fne. gy. s. One specimen.

## CHÆTODIADEMA.

Mortensen, 1903. Vid. Med. Nat. For. Kjöbenhavn, p. 1.

Type-species, *Chaetodiadema granulatum* Mortensen, 1903. Vid. Med. Nat. For. Kjöbenhavn, p. 1.

Although closely allied to *Astropyga*, this genus is easily distinguished by the much flatter test and smaller actinostome, as well as by the more important characters of the ambulacra and actinal surface, already mentioned.



There appear to be three quite distinct species in the group, of which *granulatum* Mortensen is from the East Indian region, ranging from the Maldives to New Guinea, in 10–120 fathoms; *japonicum* Mortensen is from Sagami Bay, Japan, 30 fathoms; and *pallidum* A. Agassiz and Clark is from the Hawaiian Islands, in 123–220 fathoms. These species may be distinguished as follows :

Color of test and spines brown; blue spots or a blue line along each side of bare, abactinal, interambulacral space.

At ambitus, in each interambulacrum, 10–12 columns of primary tubercles; most of actinal surface densely covered with secondary and miliary tubercles, and without primaries; blue spots at sides of abactinal interambulacra . . . . . *granulatum*.

At ambitus, in each interambulacrum, 6–8 columns of primary tubercles; most of actinal surface with primary tubercles; a blue line at sides of abactinal interambulacra . . . . . *japonicum*.

Color of test buff; spines whitish; primaries often more or less banded with purple; no blue anywhere — . . . . . *pallidum*.

### **Chætodiadema pallidum** A. Ag. and Cl.

*Chætodiadema pallidum* A. Agassiz and Clark, 1907. Bull. M. C. Z., L., p. 237.

Plates 44, figs. 5, 6; 50, figs. 16–19; 56; 59.

Of the interesting genus *Chætodiadema* Mortensen a handsome new species proves to be common in certain localities among the Hawaiian Islands (Pls. 56, 59). As stated by Mortensen<sup>1</sup> of *Ch. granulatum*, the test, when seen from above, resembles closely that of *Astropyga*, but in our species the test has not the flexibility of that of the *Echinothuridæ*.

In the tuberculation of the actinal surface this species is more closely allied to *Ch. japonicum* Mortensen (l. c. Pl. 2, figs. 16, 19) than to *granulatum* Mortensen (l. c. Pl. 1, figs. 1, 3, 21, 22), as the former species does not have the whole actinal side covered by such close and fine uniform granulation (see Pl. 59, fig. 3, and Mortensen l. c. Pl. 2, fig. 19). As Mortensen has given no detailed figures of either the actinal or abactinal systems, nor of the peculiar arrangement of the tuberculation on the actinal surface of the test, it is difficult to compare our species with the two he has described. It is apparent, however, by a comparison of the photographic figures of *Ch. pallidum* on Pl. 59 with his figures on Pl. 1, and on Pl. 2, that *pallidum*

<sup>1</sup> Danish Exp. to Siam: Echinoidea, p. 22, 1904.



is at once distinguished from *granulatum* by the comparatively large size of the abactinal system (Pl. 59, fig. 4, compare with that of *Ch. granulatum*, Pl. 1, fig. 1), which is much smaller in proportion to the size of the test. In the specimen of *pallidum*, figured in Pl. 59, figs. 3, 4, the abactinal system measures 19.50 mm., the anal system 11 mm., and the actinal system only 10.25 mm. in diameter. In a larger specimen (Pl. 59, fig. 2) the abactinal system measures 22 mm. There are no papillæ covering the genital openings, which are surrounded by a slightly raised ring (Pls. 56, figs. 2, 5; 59, fig. 4). The oculars and genitals are all in contact with the distal ring of large irregularly pentagonal anal plates, inside of which are two rings of irregularly polygonal smaller plates, and immediately at the base of the anal tube the anal membrane is covered with minute papillæ. The large anal plates carry small miliaries and an occasional secondary tubercle. The genitals as well as the oculars are sparsely covered with miliaries (Pl. 56, fig. 2). The madreporite covers the greater part of the madreporic genital (Pl. 56, fig. 5).

The actinal system is markedly pentagonal, with prominent actinal indentations. The five pairs of buccal plates form a closed ring round the mouth, and outside of them the actinal membrane is covered with a narrow belt of small more or less elliptical plates. At the actinal angle of the ambulacra a larger plate is found (Pl. 56, fig. 1). The actinal system is deeply sunken (Pl. 59, fig. 1) far more than is the case in *granulatum*, which, judging from the figure (Pl. 1, fig. 3) given by Mortensen, is comparatively flat. The actinal part of the ambulacra is most indistinct in *granulatum* (Mortens. Pl. 1, fig. 3), while in *Ch. pallidum* (Pl. 59, fig. 3) the pores form well-marked zones. The close tuberculation of the actinal surface is well shown in Pl. 59, fig. 3, and more in detail in Pl. 56, fig. 1. It will be seen that the vertical rows of primary tubercles, diminishing in size, extend almost to the actinal system, and that the close granulation of the actinal surface mentioned by Mortensen in the interambulacral area is limited to the interambulacral space of that surface and does not cover the whole actinal surface nearly to the ambitus, as is the case in *granulatum*. It is true that the large tubercles of the actinal surface of *pallidum*, which form the continuation of the vertical columns of primary tubercles from above the ambitus, are different from those at the ambitus and above it. The latter are perforate and crenulate, while the former are not usually perforate and are not crenulate (Pl. 56, fig. 5). It is quite possible in our species to distinguish

from the exterior the sutures of the primary plates both of the ambulacral and interambulacral areas in spite of the maze of granules which cover the actinal surface (see Pl. 56, figs. 1, 5). These sutures, Mortensen says, can be traced in *granulatum* only by examining the interior.

On the inner surface of the test the lapping of the interambulacral plates on the abactinal side is plainly seen; it is more marked along the sutures of the median line than along the horizontal sutures. The interambulacral plates carry minute spicular granules irregularly scattered along the median and lateral side of each plate. These granules become more numerous towards the ambitus. At the ambitus, where the rows of large tubercles begin, their presence is indicated by deep circular cavities which extend both in the interambulacral and ambulacral areas nearly to the actinostome.

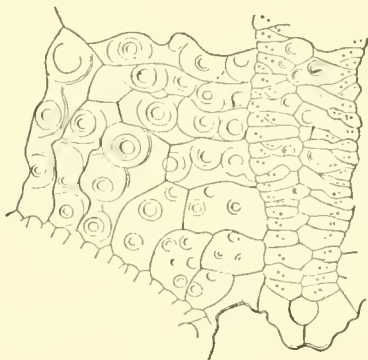


FIG. c.

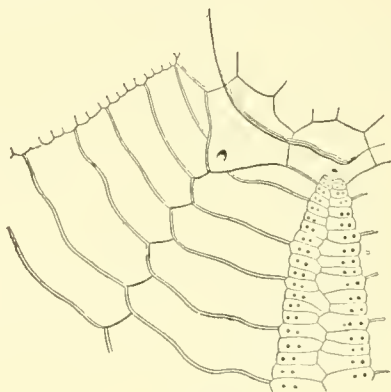


FIG. d.

The splitting of the interambulacral plates which was noticed in *Astropyga* (A. Agassiz, Challenger Echini Pl. 10\*, fig. 9) is found mainly in the larger actinal plates near the ambitus; in *Chaetodiadema* the splitting of the interambulacral plates takes place, according to Mortensen, at the median end. See figs. c and d.

Seen from the interior the ambulacral and interambulacral plates of the actinal side are covered with rows of deep pits corresponding to the rows of primary and secondary tubercles, and the surface of the plates is covered with irregularly arranged patches of minute granular spicules. The ambulacral plates on the actinal face show a splitting up into irregular plates like that of the interambulacra. The lapping of the plates on the actinal surface is not as clearly indicated as on the abactinal. The lapping of the interambulacral sutures on the actinal surface, when compared to that of the abactinal side, is most irregular, owing to the crowding of the tubercles.

The actinal plates of the ambulacral area each carry only a single pair of pores. At about the sixth (Pl. 56, fig. 4) plate from the actinostome, small secondary plates are intercalated, forming compound plates with irregular arcs of three pairs of pores. On the abactinal part of the test, except near the abactinal system, and even below the ambitus, each such plate carries a primary tubercle, perforate and crenulate, which completely obliterates the sutures of the primitive plates. The arrangement of the pores on the actinal face is thus quite different from that described by Mortensen (l. c. p. 24).<sup>1</sup>

The whole abactinal part of the interambulacral area is nearly bare, the upper six or seven plates carrying only a few miliaries and small secondaries adjoining the poriferous zone. There are six vertical rows of perforate and crenulate primary tubercles, each row consisting of three, four or five tubercles; of the outer rows three primaries are above the ambitus and two below; of the inner row three (or two) below and two (or one) above; a fourth row, between the outer two, is indicated below the ambitus by the presence of one or two primaries.

This species is readily distinguished from the two species hitherto known by its color, which is pale buff when dry, more or less tinged with purple when wet, becoming a buff white beneath. The sides of the bare interambulacral areas on the abactinal surface are more or less distinctly yellow; in many specimens the ambulacral edge of this area is marked by a broad dull red line extending from the ambitus to the genital plates (Pl. 59, fig. 2), but these lines may be interrupted, and in about half the specimens are entirely wanting. There is no blue either on the test or spines, as in the figure of *Ch. granulatum* given by de Meijere (Pl. XI, fig. 101). A similar band is prominent in one of the figures of *Ch. japonicum* given by Mortensen (l. c. Pl. 2, fig. 16). It is less distinct in *Ch. granulatum* (Mort., Pl. 1, fig. 22). Some of the individuals have on the actinal side a deep brown line, forming a more

<sup>1</sup> I would not venture to doubt the existence of the splitting of the actinal interambulacral plates as observed by Dr. Mortensen or to intimate as he has done that the splitting of the actinal interambulacral plates which I observed in *Astropyga* was probably due to rough handling of the specimens; or as he says, "and it is rather probable that the splitting up of the plates in large specimens may be due simply to the breaking of the delicate plates by the handling of the specimens." This is but one of the many instances of acidulous criticism and endless fault finding indulged in by Dr. Mortensen. He is constantly objecting to this or that figure as being bad. I would call his attention to the very unsatisfactory figures he has given of *Chætodiadema granulatum* and *Ch. japonicum* on Plates I, figs. 1, 3, and II, figs. 16, 19 of his Siam Ex. Echini, and to the confusion he creates, far more aggravating than anything he finds to correct, by his irregular numbering on the same Plate of figures belonging to the same species (Pl. I, 1, 3, 21, 22; Pl. II, figs. 16, 19); his standard of convenience and of excellence is a most variable quantity. —A. AGASSIZ.

or less perfect pentagon round the actinostome, about one third of the distance to the ambitus.

The primary radioles are slender (Pl. 56, figs. 6, 7; 59, figs. 1, 2), of moderate but variable length, the longest equalling the diameter of the test. They are decidedly flattened, nearly white, but many have a purplish longitudinal stripe on the abactinal side, and not infrequently they are handsomely banded with purple (Pl. 56, fig. 6). The whole length of the shaft is finely serrated in close longitudinal lines. The verticillation is very delicate, caused by longitudinal furrows alternating with the irregular longitudinal rows of minute teeth (Pl. 56, figs. 6, 7).

The aspect of this species as seen from the abactinal surface (Pl. 59, fig. 2), with its primary spines limited to the ambitus and extending but a few plates towards the abactinal system, and its bare abactinal interambulacral areas with the few scattered, thin, sharp secondary spines, is in striking contrast to its appearance as seen from the actinal side (Pl. 59, fig. 1); see also Mortensen, Siam. Echini, Pl. 1, fig. 21. The primary spines are limited to the vicinity of the ambitus, and on the rest of the actinal surface the secondary and miliary spines are short, slightly curved or club-shaped, and flattened at the tip and striated; so that on a first examination it would seem as if the actinostome with its small spines extended far out towards the ambitus.

The specimens range in diameter from 42 to 70 mm. The test is very flat, the greatest height being only .25-.30 of the diameter (Pl. 59, fig. 5), the abactinal system is .30-.42, and the actinal only .17-.24 of the diameter, while the anal system is .60-.65 of the abactinal. The test is relatively higher, and the abactinal and actinal systems larger, in small than in large individuals.

Dr. Mortensen, after laying great stress (by printing it in capitals) upon the uniform granulation of the actinal surface as typical of the genus *Chætodiadema*, modifies this in ordinary print a few pages further on, when describing *Ch. japonicum*.

One of the most striking characters of this interesting species is the extraordinary scarcity of pedicellariæ. Careful and long-continued examination of ten specimens brought to light only a single tridentate pedicellaria, and that had the tip broken off. It was of the *slender tridentate* form, with the valves meeting only near the tip. These valves (Pl. 50, figs. 16, 17) when complete would have measured about a millimeter and a half in length, with the strongly compressed blade hardly a tenth as wide. The



margin is coarsely dentate. The most characteristic feature is the very conspicuous apophysis, which is nearly twice as high as the depth of the basal part of the pedicellaria and is abruptly truncate at the end. Such an apophysis is quite unique and it is unfortunate that the slender tridendate pedicellariæ appear to be so exceedingly rare.

The *triphylloous* pedicellariæ are infrequent, but occur here and there, more particularly on the ambulacra. They are very small, and of simple structure. The valves (Pl. 50, fig. 18) are .15-.20 mm. in length, while the stalks are five or six times as long. The blade is oval, rounded at the tip and without any trace of a cover-plate.

The calcareous particles in the pedicels are very infrequent, but are somewhat more plentiful in the gills (Pl. 50, fig. 19). They are not peculiar, except for their small size, and usually show their triradiate origin very plainly, though some of the plates may have seven or eight perforations.

The sphæridia are much more common than in the other species of the genus, for there may be as many as sixteen in an ambulacrum. They do not occur near the peristome, but are first found about three-fifths of the distance from that point to the ambitus. In all cases they are found at or near the ambitus, and not infrequently they are placed on the abactinal surface. They are nearly globular and of moderate size, about .30 mm. in diameter. They are placed in very evident depressions or hollows in the test, and are distinctly pendent from the upper side of the hollow.

This species was taken by the "Albatross" at the following stations:

Station 3856. Pailolo Channel, between Maui and Molokai, Hawaiian Islands. Bott. temp. 66.5°. 127 fathoms. Fne. s. yl. m.

Station 3857. Pailolo Channel, between Maui and Molokai, H. I. Bott. temp. 62.5°. 127-128 fathoms. Fne. s. yl. m.

Station 3957. Vicinity of Laysan Island, H. I. Bott. temp. 53.5°. 173-220 fathoms. Fne. wh. s.

Station 4103. Pailolo Channel, between Maui and Molokai, H. I. Bott. temp. 61.7°. 132-141 fathoms. Fne. gy. s.

Station 4104. Pailolo Channel, between Maui and Molokai, H. I. Bott. temp. 60.8°. 123-141 fathoms. Fne. gy. s. for.

Bathymetrical range, 123-220 fathoms. Extremes of temperature, 66.5°-53.5°.

Eighty-two specimens.



## LISSODIADEMA.

Mortensen, 1903. Rev. Suisse de Zool., XI, p. 393.

Type-species, *Lissodiadema Lorioli* Mortensen, 1903. Rev. Suisse de Zool., XI, p. 393.

The two specimens upon which this genus and species are based were taken at Amboina. They measure 10 and 22 mm. in diameter and were regarded by de Loriol, who first described them, as young individuals, possibly of *Asthenosoma*. Mortensen has shown that they can hardly be young Echinothurids, and are almost certainly Diadematids, though they are unlike any known young of the latter family. The genital pores are undeveloped, and they appear in other ways to be immature, yet it seems to be necessary to give them a genus of their own, at least for the present.

## LEPTODIADEMA.

A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 238.

Type-species, *Leptodiadema purpureum* A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 239.

This genus is established for a very small Diadematoid apparently quite different from any known genus. The size, form, and spines remind one of *Lissodiadema*, and the abactinal system is not altogether unlike that genus, but the tuberculation is entirely different. The test is flattened both actinally and abactinally; the ambulacra narrow, with pores in a single straight series not becoming crowded at the actinostome. Each ambulacrum carries a double series of primary tubercles extending from the abactinal system to the actinostome. The coronal plates are numerous, each with a large primary tubercle at the outer end. Below the ambitus these tubercles are increasingly nearer the center of the plate, so that the two series converge and meet at the actinostome. Beginning at the fifth from the abactinal system, each coronal plate carries a second somewhat smaller tubercle at the inner end, and these two series terminate at about the fourth plate from the actinostome. Secondary spines few, miliaries almost wanting. The primary tubercles are low, indistinctly perforate and apparently finely crenulate. From the ambitus to the abactinal system the ambulacral tubercles are small. On the actinal side the tubercles of both systems are nearly uniform in size.

Abactinal system moderate, the oculars on each side of the madreporic plate and the left anterior one are excluded from, while the other oculars extend to, the large anal system, which is covered with two rows of plates,

an outer row of larger plates and an inner row of small plates surrounding the anal opening.

The two anterior genitals are roughly heptagonal, the right and left posterior genitals are hexagonal, and the odd posterior genital is pentagonal. In all five the genital openings are well developed and surrounded by a raised ring.

The actinostome is somewhat larger than the abaetinal system; actinal cuts slight; buccal membrane closely covered with narrow elongate plates, as in young *Diadema*, arranged in five wedge-shaped, ambulacral divisions; buccal plates large, in five approximated pairs. Primary radioles about half the diameter of the test, those of the ambulacra scarcely shorter or more slender than the others; all are delicate, glassy, slightly curved, and blunt, with five to seven prominent ridges, two of which (on opposite sides of the spine) may bear, at least near the base, a few widely separated, very slender teeth.

### ***Leptodiadema purpureum* A. Ag. and Cl.**

*Leptodiadema purpureum* A. Agassiz and Clark, 1907. Bull. M. C. Z., L, p. 239.

Plates 50, figs. 20, 21; 55, figs. 7-10.

The single specimen obtained is 9 mm. in diameter with 13-14 coronal, interambulacral plates. The color is dull purplish, becoming bright purple on the buccal membrane. The spines are nearly colorless. The two anterior genital plates are larger than the posterior ones. The genital openings are nearly in the centre of the irregularly pentagonal plates, and are surrounded by a small protuberance. The madreporic body is well marked (Pl. 55, fig. 8). The oculars are pentagonal or hexagonal, and the three anterior are excluded from the anal system. The distal part of the actinal system beyond the five pairs of large buccal plates is covered with long narrow plates arranged in five separate wedge-shaped groups, one in each ambulacrum. On the actinal side of the test the primary tubercles of both the ambulacral and interambulacral areas are nearly of the same size (Pl. 55, fig. 7); but above the ambitus the tubercles of the ambulacral system are quite small (Pl. 55, fig. 8). The median abaetinal part of the interambulacral area is nearly bare, only a very few miliaries and secondaries being carried by the four uppermost abaetinal plates.

No pedicellariæ of any kind were present in the single specimen of this species, possibly further evidence of its immaturity.

The calcareous particles in the pedicels (Pl. 50, fig. 21) were numerous and characteristic. They are distinctly triradiate, but the branches are more or less curved and often give off secondary branches. They do not, however, become perforated plates.

The sphaeridia (Pl. 50, fig. 20), of which several are pendent in each ambulacrum, are variable in shape, some being nearly globular, while others are much longer than thick.

The single specimen of this species was taken by the "Albatross" at Station 3847. Off Lae-o Ka Laau Light, Molokai, Hawaiian Islands. 23-24 fathoms. S. st.

## EXPLANATION OF THE PLATES.

The abbreviations used on Plates 43 and 44 are as follows :

*as* = abactinal system of plates, seen from within.

*cts* = connective tissue strands.

*go* = reproductive organs.

*l* = lantern, seen from above.

*lc* = lower, or actinal, half of stomach-intestine.

*m* = mesentery.

*oe* = œsophagus.

*pg* = perignathic girdle.

*r* = rectum.

*sc* = stone-canal.

*uc* = upper, or abactinal, half of stomach-intestine.

In all abactinal and actinal views of the entire animal and of the denuded test, and in Pls. 43, 44, and 56, figs. 1, 2, the anterior ambulacrum is uppermost.

PLATE 43.

Showing the Arrangement of the Digestive and Reproductive Organs.

1, 2. *Porocidaris variabilis* A. Ag. and Cl.

1. Interior view of abactinal half of test, with organs in place. Nat. size.
2. Interior view of actinal half. Nat. size.

3, 4. *Salenia Pattersoni* A. Ag.

3. Interior view of abactinal half of test, with organs in place.  $\times 3$ .
4. Interior view of actinal half.  $\times 3$ .

5, 6. *Salenocidaris miliaris* A. Ag. and Cl.

5. Interior view of abactinal half of test, with organs in place.  $\times 3$ .
6. Interior view of actinal half.  $\times 3$ .



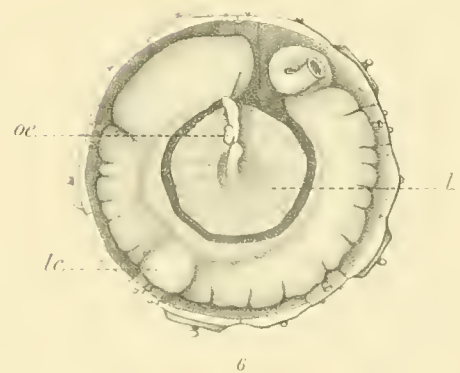
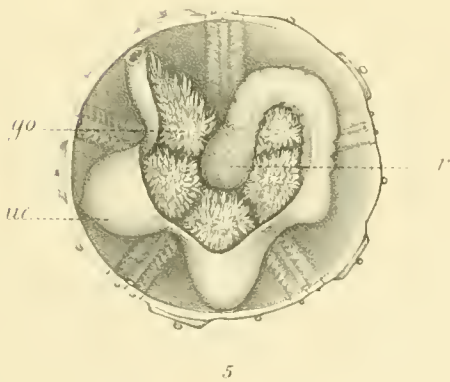
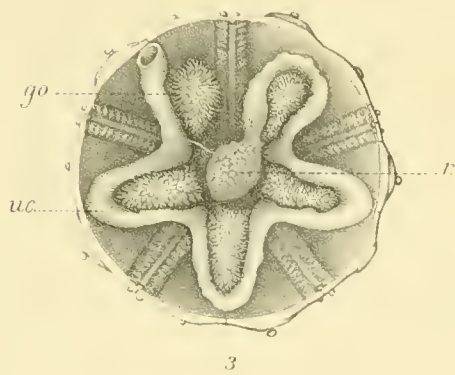
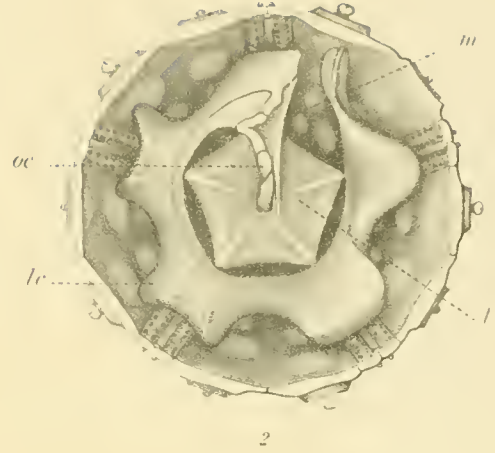
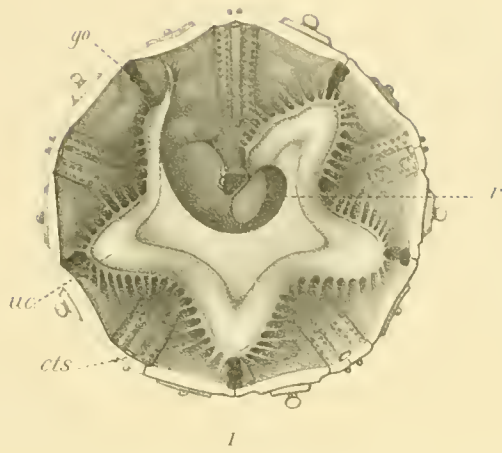




PLATE 44.

PLATE 44.

Showing the Arrangement of the Digestive and Reproductive Organs.

1, 2. *Cœlopleurus floridanus* A. Ag.

1. Interior view of abactinal half of test, with organs in place.  $\times 2$ .
2. Interior view of actinal half.  $\times 2$ .

3, 4. *Aspidodiadema meijerei* A. Ag. and Cl.

3. Interior view of abactinal half of test, with organs in place.  $\times 2$ .
4. Interior view of actinal half.  $\times 2$ .

5, 6. *Chaetodiadema pallidum* A. Ag. and Cl.

5. Interior view of abactinal half of test, with organs in place. Nat. size.
6. Interior view of actinal half. Nat. size.

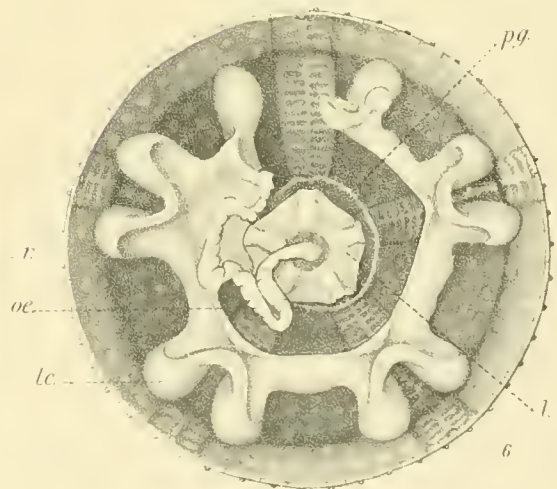
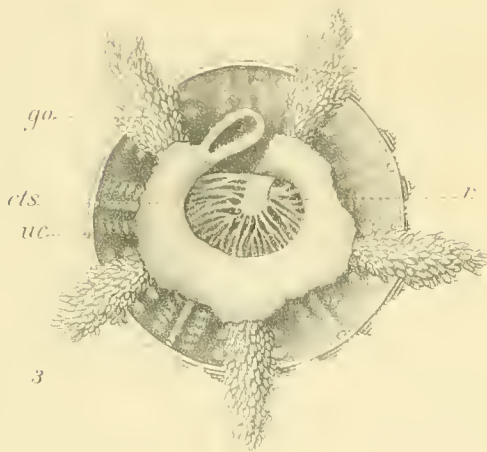
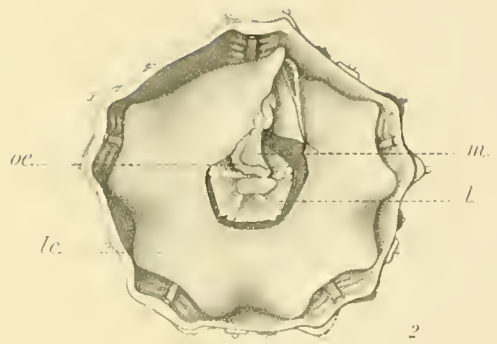






PLATE 45.

PLATE 45.

1-8. *Salenocidaris miliaris* A. Ag. and Cl.

1. Quadridentate pedicellaria.  $\times 55$ .
2. Valve of quadridentate pedicellaria.  $\times 55$ .
3. Tridentate pedicellaria.  $\times 55$ .
4. Ovoid pedicellaria.  $\times 55$ .
5. Valve of ovoid pedicellaria.  $\times 156$ .
6. Globose pedicellaria.  $\times 55$ .
7. Valve of globose pedicellaria.  $\times 156$ .
8. Sphæridium.  $\times 70$ .

9. *Salenocidaris crassispina* A. Ag. and Cl.

9. Spicules from pedicels.  $\times 215$ .

10-15. *Salenocidaris varispina* A. Ag.

10. Valve of tridentate pedicellaria.  $\times 70$ .
11. Side view of similar valve.  $\times 70$ .
12. Valve of ovoid pedicellaria.  $\times 70$ .
13. Valve of globose pedicellaria.  $\times 70$ .
- 14, 15. Sphæridia.  $\times 70$ .

16-21. *Salenocidaris profundus* A. Ag. and Cl.

16. Valve of tridentate pedicellaria.  $\times 70$ .
17. Valve of a smaller tridentate pedicellaria.  $\times 70$ .
18. Ovoid pedicellaria.  $\times 70$ .
19. Valve of globose pedicellaria.  $\times 70$ .
20. Spicules from pedicels.  $\times 215$ .
21. Sphæridium.  $\times 70$ .

22-25. *Salenia cincta* A. Ag. and Cl.

22. Valve of globose pedicellaria.  $\times 70$ .
23. Valve of ovoid pedicellaria.  $\times 70$ .
24. Stalk of globose pedicellaria.  $\times 70$ .
25. Sphæridium.  $\times 70$ .

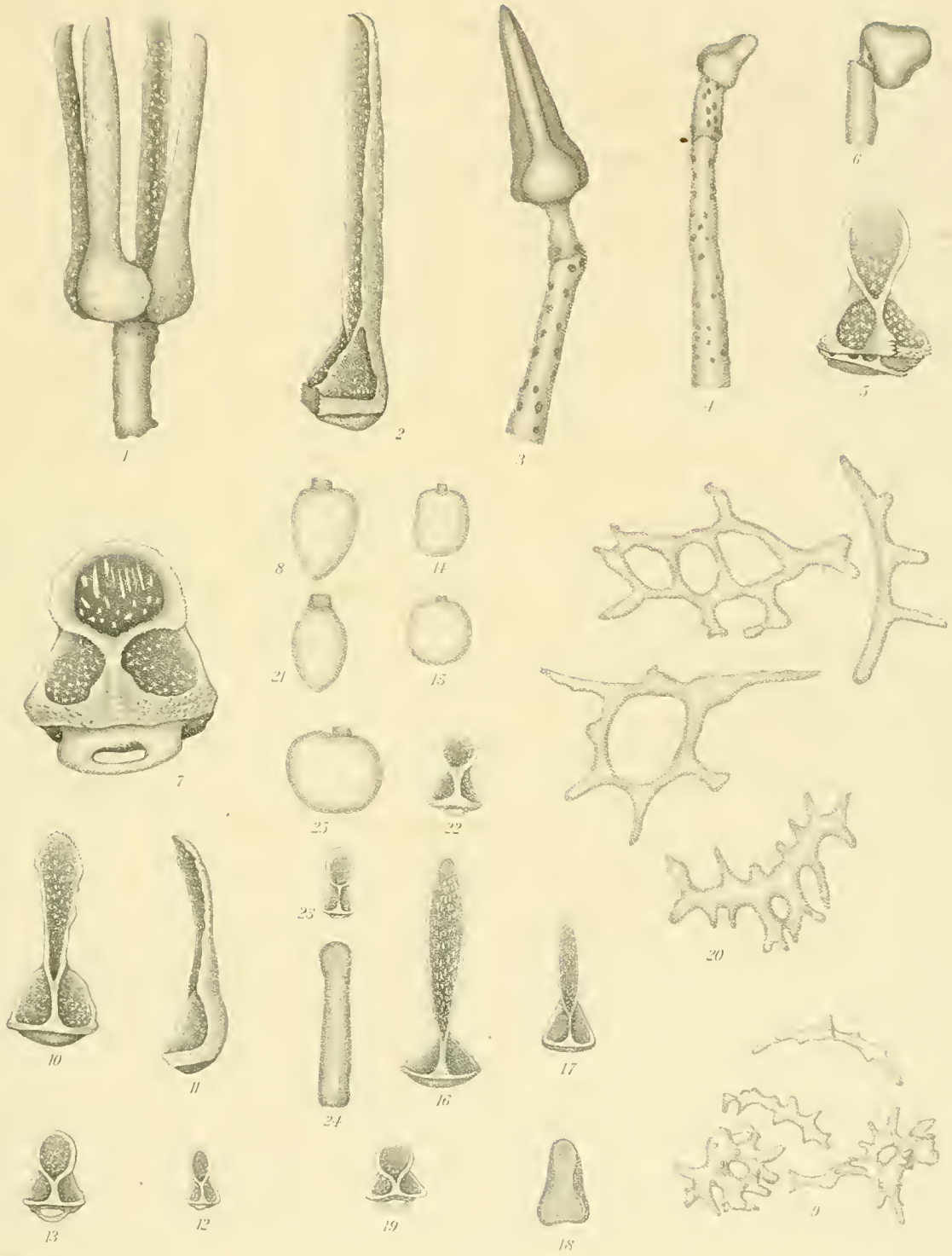






PLATE 46.

PLATE 46.

1-8. *Salenia Pattersoni* A. Ag.

1. Valve of quadridentate pedicellaria.  $\times 70$ .
2. Side view of valve of another quadridentate pedicellaria.  $\times 70$ .
3. Valve of tridentate pedicellaria.  $\times 70$ .
4. Valve of globose pedicellaria.  $\times 70$ .
5. Valve of ovoid pedicellaria.  $\times 70$ .
6. Valve of another ovoid pedicellaria.  $\times 70$ .
7. Spicules from pedicels.  $\times 215$ .
8. Sphæridium.  $\times 70$ .

9-16. *Dialithocidaris gemmifera* A. Ag.

9. Tridentate pedicellaria.  $\times 30$ .
10. Valve of tridentate pedicellaria, from side.  $\times 70$ .
11. Valve of tridentate pedicellaria; interior view of base.  $\times 70$ .
12. Stalk of tridentate pedicellaria, after treatment with alkali.  $\times 70$ .
13. Ophicephalous pedicellaria.  $\times 30$ .
14. Large valve of ophicephalous pedicellaria.  $\times 70$ .
15. Small valve of ophicephalous pedicellaria.  $\times 70$ .
16. Valve of triphyllous pedicellaria.  $\times 70$ .

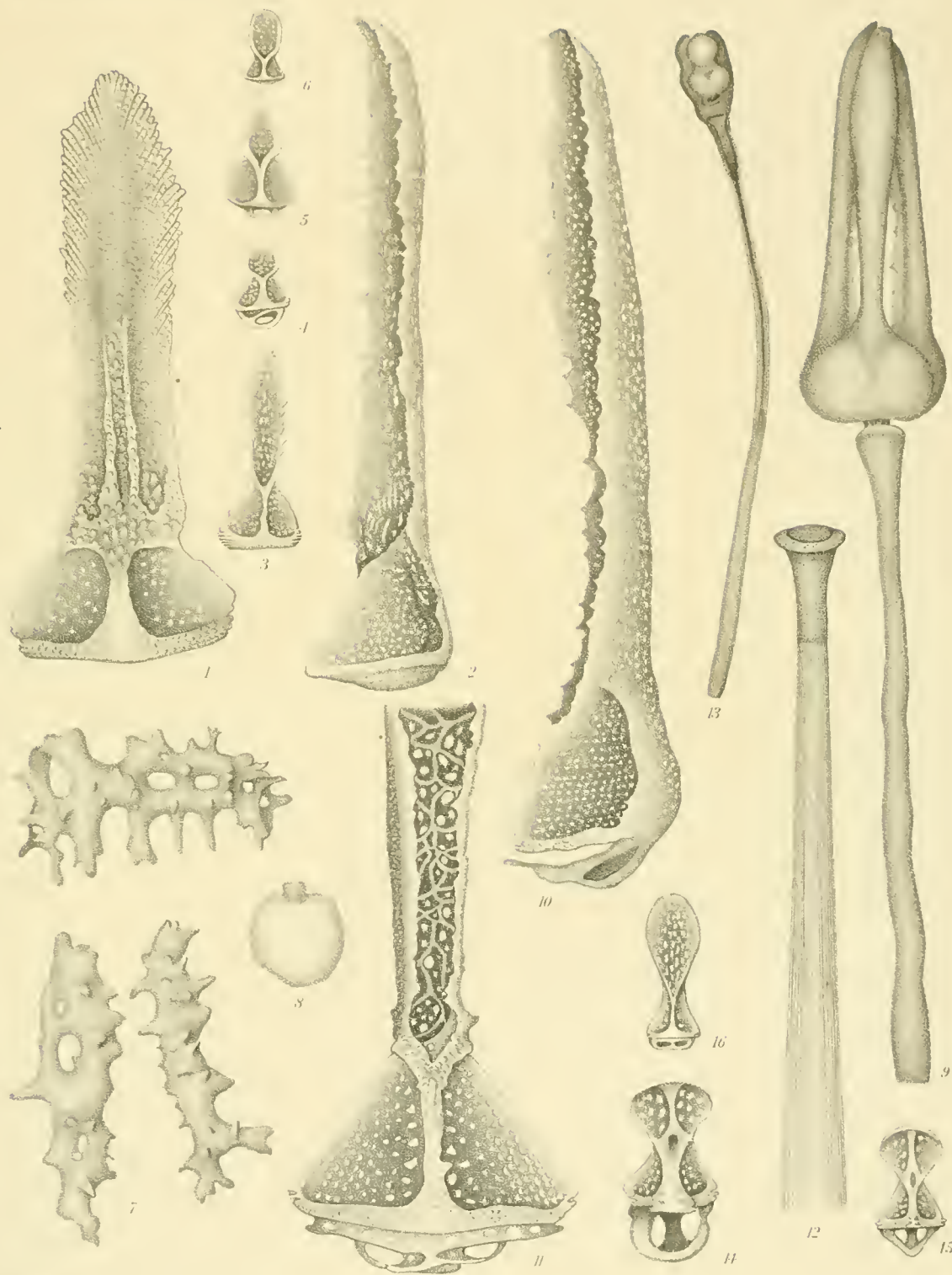




PLATE 47.



PLATE 47.

1-11. *Arbacia Dufresnii* Gray.

1. Tridentate pedicellaria.  $\times 30$ .
2. Ophicephalous pedicellaria.  $\times 30$ .
3. Triphyllous pedicellaria.  $\times 30$ .
4. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
5. Valve of tridentate pedicellaria.  $\times 70$ .
6. Valve of triphyllous pedicellaria.  $\times 70$ .
7. Valve (*b*) of ophicephalous pedicellaria.  $\times 70$ .
8. Basal part of second valve (*a*) of same ophicephalous pedicellaria.  $\times 70$ .
9. Basal part of third valve (*c*) of same ophicephalous pedicellaria.  $\times 70$ .
10. Sphæridium.  $\times 70$ .
11. Calcareous plates from gills.  $\times 70$ .

12-16. *Tetrapygyus niger* Agass.

12. Valve of tridentate pedicellaria.  $\times 70$ .
13. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
14. Valve of ophicephalous pedicellaria.  $\times 70$ .
15. Sphæridium from a small individual.  $\times 70$ .
16. Sphæridium from a large individual.  $\times 70$ .

17-19. *Arbacia punctulata* Gray.

17. Sphæridium.  $\times 70$ .
18. Upper ends of stalks of ophicephalous pedicellariæ.  $\times 70$ .
19. Calcareous plates from gills.  $\times 70$ .





PLATE 48.

PLATE 48.

1-9. *Arbacia punctulata* Gray.

1. Valve of tridentate pedicellaria.  $\times 70$ .
2. Valve of large tridentate pedicellaria.  $\times 70$ .
3. Valve of small tridentate pedicellaria.  $\times 70$ .
4. Valve of triphyllous pedicellaria.  $\times 70$ .
5. Valve of ophicephalous pedicellaria.  $\times 70$ .
6. Another valve of another ophicephalous pedicellaria.  $\times 70$ .
7. Disk-plate of pedicel.  $\times 70$ .
8. Supporting-plate of disk of pedicel.  $\times 70$ .
9. Calcareous rods from pedicels.  $\times 70$ .

10-14. *Arbacia lixula* Lovén.

10. Valve of tridentate pedicellaria.  $\times 70$ .
11. Valve of smaller tridentate pedicellaria.  $\times 70$ .
12. Valve of very small tridentate pedicellaria.  $\times 70$ .
13. Valve of triphyllous pedicellaria.  $\times 70$ .
14. Valve of ophicephalous pedicellaria.  $\times 70$ .

15-19. *Arbacia spatuligera* A. Ag.

15. Valve of tridentate pedicellaria.  $\times 70$ .
16. Valve of triphyllous pedicellaria.  $\times 70$ .
17. Calcareous rods from pedicels.  $\times 70$ .
18. Upper end of stalks of pedicellariæ.  $\times 70$ .
19. Sphæridium.  $\times 70$ .

20, 21. *Arbacia stellata* Gray.

20. Valve of triphyllous pedicellaria.  $\times 70$ .
21. Calcareous plates from pedicels.  $\times 70$ .



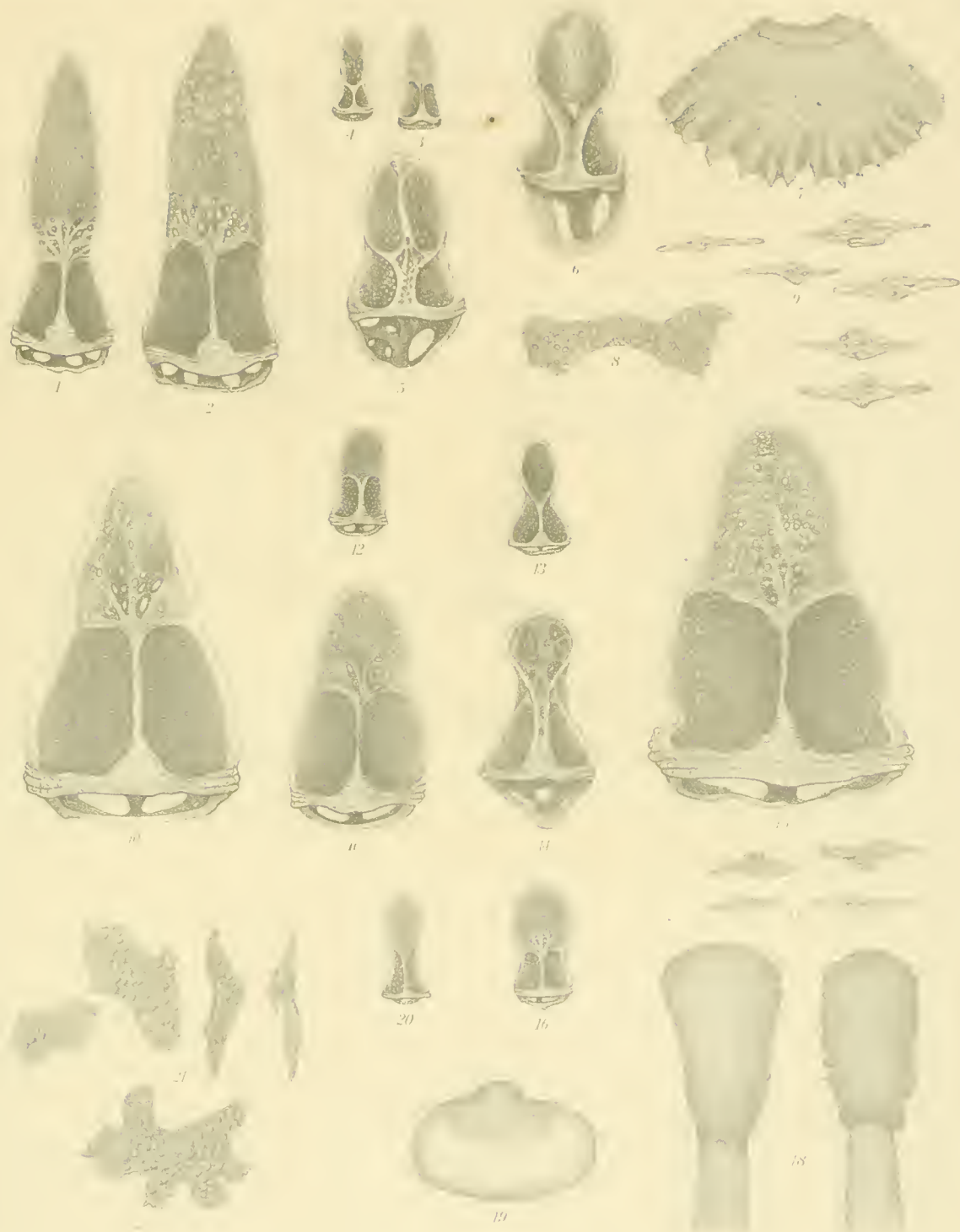




PLATE 49.

PLATE 49.

1-8 *Podocidaris sculpta* A. Ag.

1. Sphæridium in position on test.  $\times 70$ .
2. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
3. Calcareous rods from pedicels.  $\times 70$ .
4. Valve of ophicephalous pedicellaria.  $\times 70$ .
5. Terminal part of another valve of similar pedicellaria.  $\times 70$ .
6. Valve of tridentate pedicellaria.  $\times 70$ .
7. Terminal part of another valve of similar pedicellaria.  $\times 70$ .
8. Valve of triphyllous (small tridentate?) pedicellaria.  $\times 70$ .

9-14. *Habrocidaris argentea* A. Ag. and Cl.

9. Sphæridium.  $\times 70$ .
10. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
11. Calcareous rods from pedicels.  $\times 70$ .
12. Valve of ophicephalous pedicellaria.  $\times 70$ .
13. Basal part of largest valve of similar pedicellaria.  $\times 70$ .
14. Valve of tridentate pedicellaria.  $\times 70$ .

15-20. *Habrocidaris scutata* A. Ag. and Cl.

15. Sphæridium.  $\times 70$ .
16. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
17. Valve of ophicephalous pedicellaria.  $\times 70$ .
18. Basal part of largest valve of similar pedicellaria.  $\times 70$ .
19. Valve of tridentate pedicellaria.  $\times 70$ .
20. Calcareous rods from pedicels.  $\times 70$ .

21-28. *Cœlopleurus maculatus* A. Ag. and Cl.

21. Valve of ophicephalous pedicellaria.  $\times 70$ .
22. Upper end of stalk of ophicephalous pedicellaria.  $\times 70$ .
23. Valve of large tridentate pedicellaria.  $\times 70$ .
24. Valve of very small tridentate (triphyllous?) pedicellaria.  $\times 70$ .
25. Upper end of stalk of tridentate pedicellaria.  $\times 70$ .
26. Sphæridial cavity with sphæridium in place.  $\times 70$ .
27. Calcareous particles from pedicels.  $\times 70$ .
28. Calcareous particles from gills.  $\times 70$ .

29, 30. *Cœlopleurus longicollis* A. Ag. and Cl.

29. Valve of ophicephalous pedicellaria.  $\times 70$ .
30. End of stalk of tridentate pedicellaria.  $\times 70$ .

31-33. *Cœlopleurus floridanus* A. Ag.

31. Valve of ophicephalous pedicellaria.  $\times 70$ .
32. Valve of tridentate pedicellaria.  $\times 70$ .
33. Valve of small tridentate (triphyllous?) pedicellaria.  $\times 70$ .

34. *Cœlopleurus Maillardi* A. Ag.

34. Valve of ophicephalous pedicellaria.  $\times 70$ .

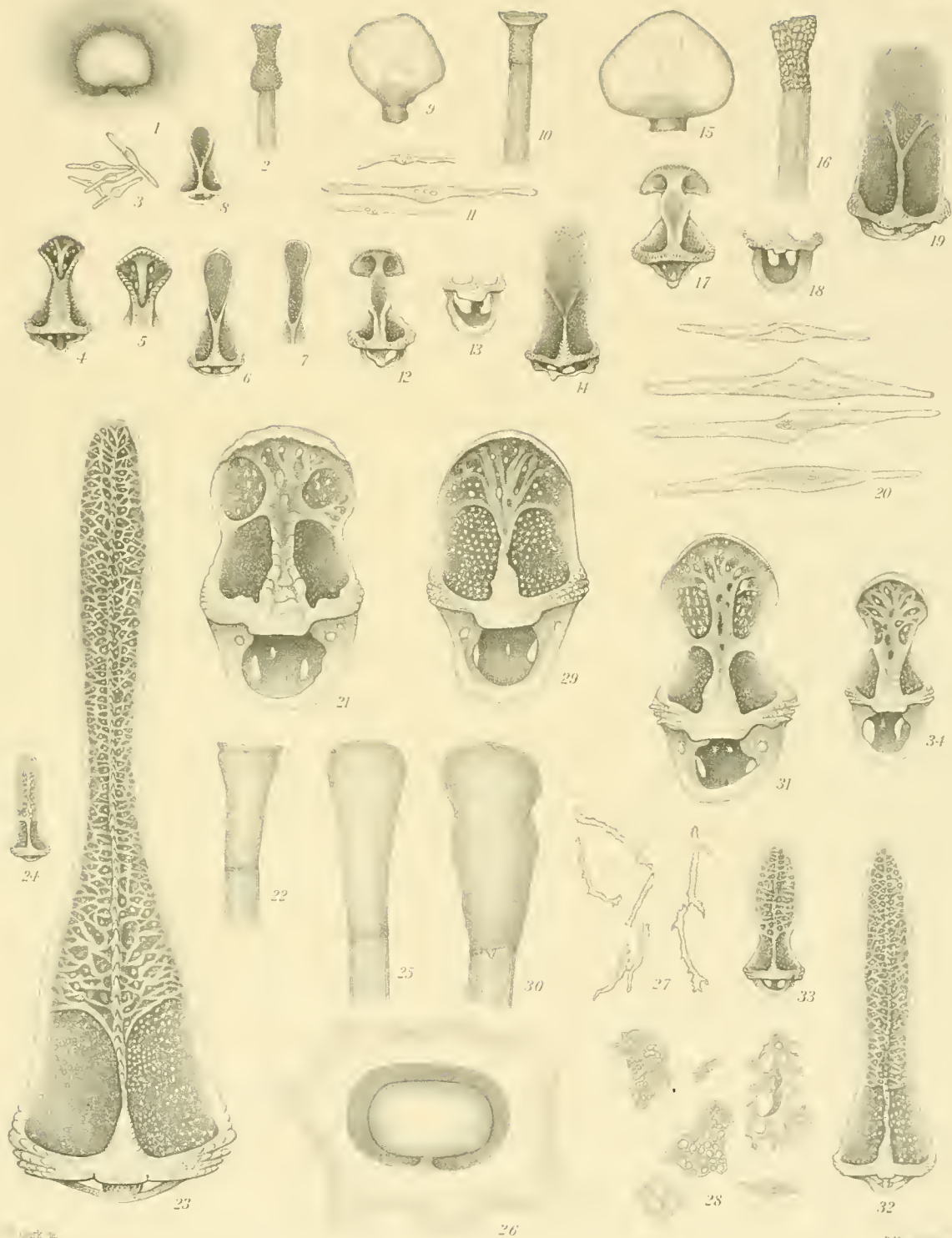






PLATE 50.

PLATE 50.

1, 2. *Aspidodiadema nicobaricum* Död.

1. Valve of stout tridentate pedicellaria.  $\times 70$ .
2. Sphæridium.  $\times 70$ .

3-5. *Aspidodiadema tonsum* A. Ag.

3. Valve of stout tridentate pedicellaria, "form *b*."  $\times 70$ .
4. Valve of pedicellaria midway between tridentate and ophicephalous, "form *c*."  $\times 70$ .
5. Valve of broad triphyllous pedicellaria.  $\times 70$ .

6-10 *Dermatodiadema globulosum* A. Ag.

6. Valve of stout tridentate pedicellaria.  $\times 70$ .
7. Valve of slender tridentate pedicellaria.  $\times 70$ .
8. Valve of triphyllous pedicellaria.  $\times 70$ .
9. Valve of ophicephalous pedicellaria.  $\times 70$ .
10. Sphæridium.  $\times 70$ .

11-15. *Dermatodiadema horridum* A. Ag.

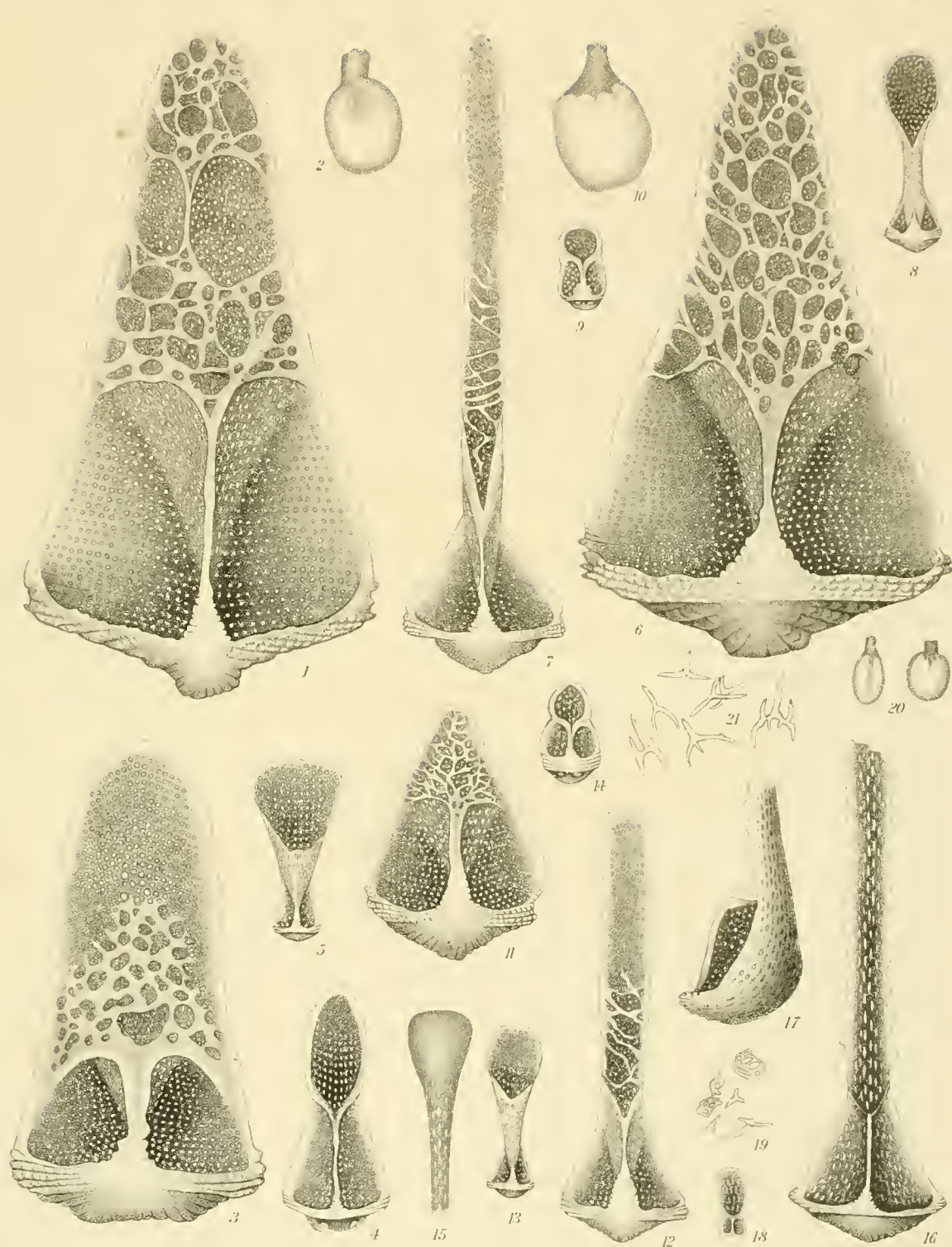
11. Valve of stout tridentate pedicellaria.  $\times 70$ .
12. Valve of slender tridentate pedicellaria.  $\times 70$ .
13. Valve of triphyllous pedicellaria.  $\times 70$ .
14. Valve of ophicephalous pedicellaria.  $\times 70$ .
15. Upper end of stalk of pedicellaria.  $\times 70$ .

16-19. *Chætodiadema pallidum* A. Ag. and Cl.

16. Valve of tridentate pedicellaria (broken at tip).  $\times 70$ .
17. Side view of base of same.  $\times 70$ .
18. Valve of triphyllous pedicellaria.  $\times 70$ .
19. Calcareous particles from gills.  $\times 70$ .

20, 21. *Leptodiadema purpureum* A. Ag. and Cl.

20. Sphæridia.  $\times 70$ .
21. Calcareous particles from pedicels.  $\times 70$ .



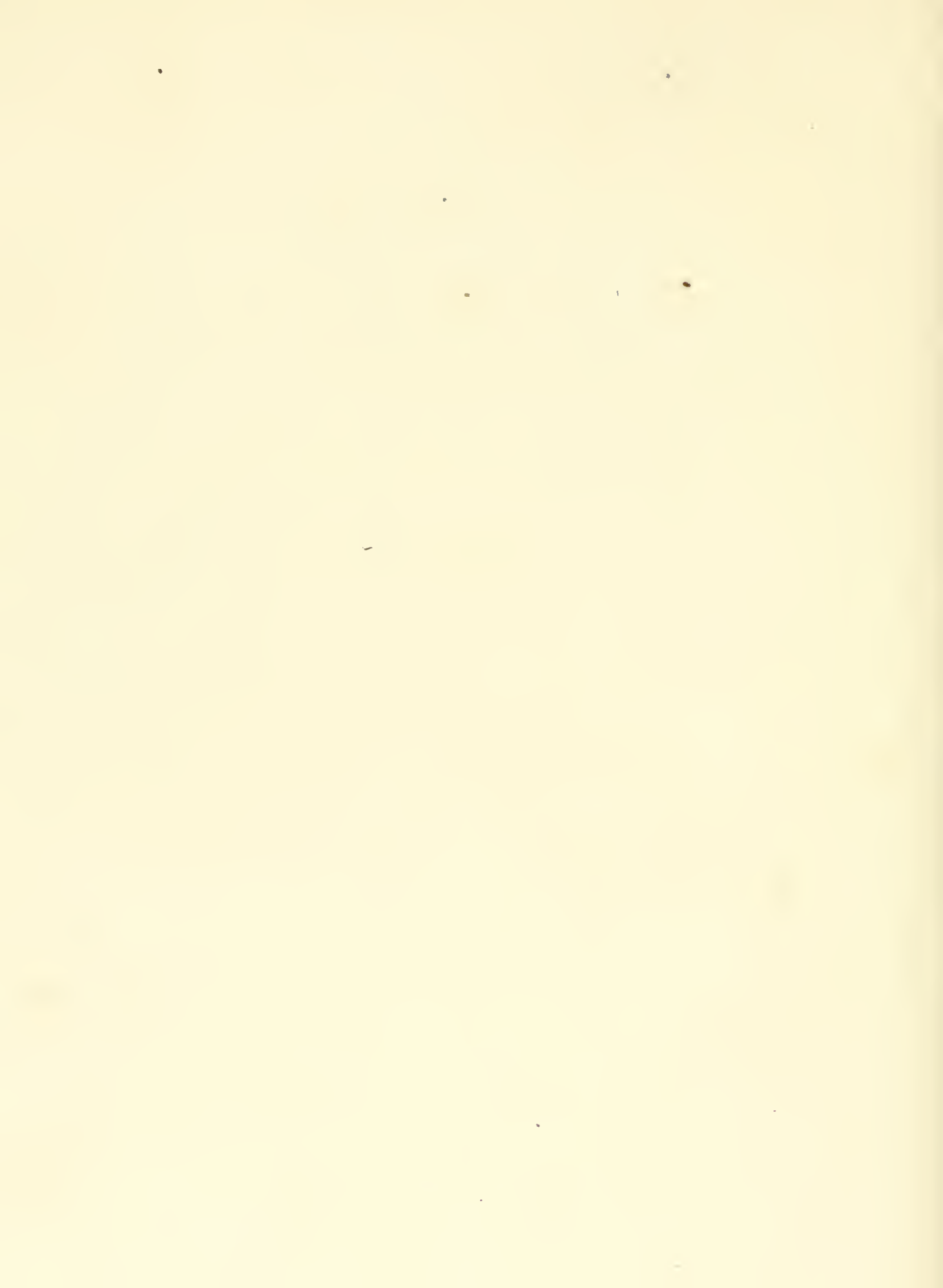




PLATE 51.

PLATE 51.

1, 2. *Diadema paucispinum* A. Ag.

1. Valve of large tridentate pedicellaria.  $\times 70$ .
2. Part of margin of same, seen from side.  $\times 70$ .

3-11. *Centrostephanus asteriscus* A. Ag. and Cl.

3. Slender tridentate pedicellaria.  $\times 70$ .
4. Stout tridentate pedicellaria.  $\times 70$ .
5. Large ophicephalous pedicellaria without glands.  $\times 70$ .
6. Ophicephalous pedicellaria with glands.  $\times 70$ .
7. Triphyllous pedicellaria.  $\times 70$ .
8. Globiferous pedicellaria.  $\times 70$ .
9. Side view of valve of globiferous pedicellaria.  $\times 70$ .
10. Interior view of base of same.  $\times 70$ .
11. Calcareous particles from pedicels.  $\times 70$ .

12-20. *Centrostephanus coronatus* A. Ag.

12. Slender tridentate pedicellaria.  $\times 70$ .
13. Stout tridentate pedicellaria.  $\times 70$ .
14. Ophicephalous pedicellaria.  $\times 70$ .
15. Triphyllous pedicellaria.  $\times 70$ .
16. Globiferous pedicellaria.  $\times 70$ .
17. Globiferous pedicellaria with glands on stalk.  $\times 70$ .
18. Side view of valve of globiferous pedicellaria.  $\times 70$ .
19. Interior view of base of same.  $\times 70$ .
20. Upper end of stalk of globiferous pedicellaria.  $\times 70$ .





PLATE 52.



PLATE 52.

1-7. *Salenocidaris crassispina* A. Ag. and Cl.

1. Actinal view of denuded test.  $\times 10$ .
2. Abactinal view of same.  $\times 10$ .
3. Left anterior ambulacrum.  $\times 10$ .
4. Right posterior interambulacrum.  $\times 10$ .
5. Primary spine.  $\times 4$ .
6. Base of primary spine.  $\times 8$ .
7. Tip of primary spine.  $\times 8$ .

8-13. *Salenia cincta* A. Ag. and Cl.

8. Actinal view of denuded test.  $\times 4$ .
9. Abactinal view of same.  $\times 4$ .
10. Odd anterior ambulacrum.  $\times 4$ .
11. Left posterior interambulacrum.  $\times 4$ .
12. Base of primary spine.  $\times 4$ .
13. Tip of primary spine.  $\times 4$ .

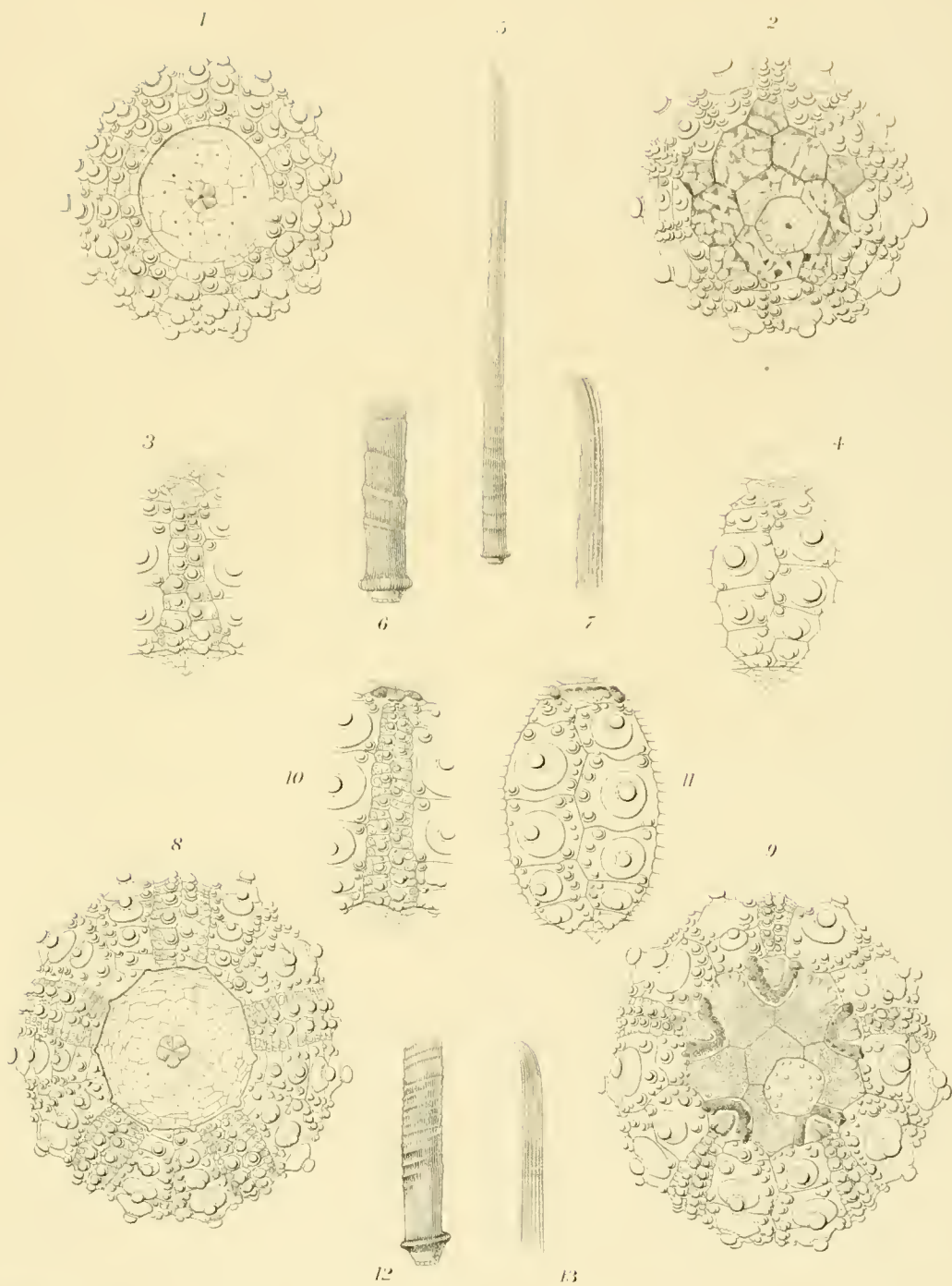




PLATE 53.

PLATE 53.

1-7. *Cœlopleurus maculatus* A. Ag. and Cl.

1. Actinal view of denuded test.  $\times 2$ .
2. Abactinal view of same.  $\times 2$ .
3. Odd anterior ambulacrum.  $\times 2$ .
4. Left posterior interambulacrum.  $\times 2$ .
5. Primary spine, seen from side.  $\times 1.5$ .
6. Base of primary spine, seen from above.  $\times 4$ .
7. Tip of primary spine, seen from above.  $\times 4$ .

8, 9. *Cœlopleurus Maillardi* A. Ag.

8. Primary spine of type specimen from Bourbon.  $\times 1.5$ .
9. Primary spine of young specimen from Kei Islands.  $\times 1.5$ .

10. *Cœlopleurus longicollis* A. Ag. and Cl.

10. Primary spine of type specimen.  $\times 1.5$ .

11. *Cœlopleurus floridanus* A. Ag.

11. Primary spine.  $\times 1.5$ .





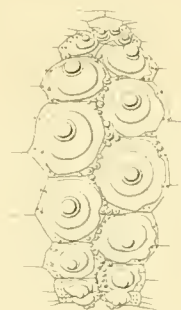
1



2



5



3



4



9



6



7



10



11



PLATE 54.

PLATE 54.

1-3. *Habrocidaris argentea* A. Ag. and Cl.

1. Actinal view of denuded test.  $\times 4$ .
2. Abactinal view of same.  $\times 4$ .
3. Right anterior interambulacrum.  $\times 4$ .

4-9. *Habrocidaris scutata* A. Ag. and Cl.

4. Actinal view of denuded test.  $\times 3$ .
5. Abactinal view of same.  $\times 3$ .
6. Side view of same, showing left anterior ambulacrum.  $\times 3$ .
7. Left anterior interambulacrum.  $\times 3$ .
8. Part of primary spine.  $\times 6$ .
9. Cross-section of spine.  $\times 8$ .



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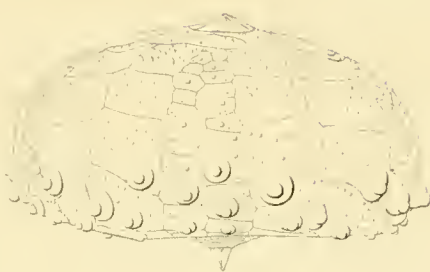


2

6



3



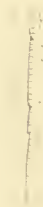
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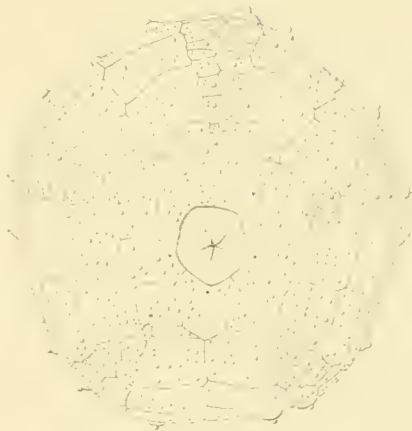
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PLATE 55.

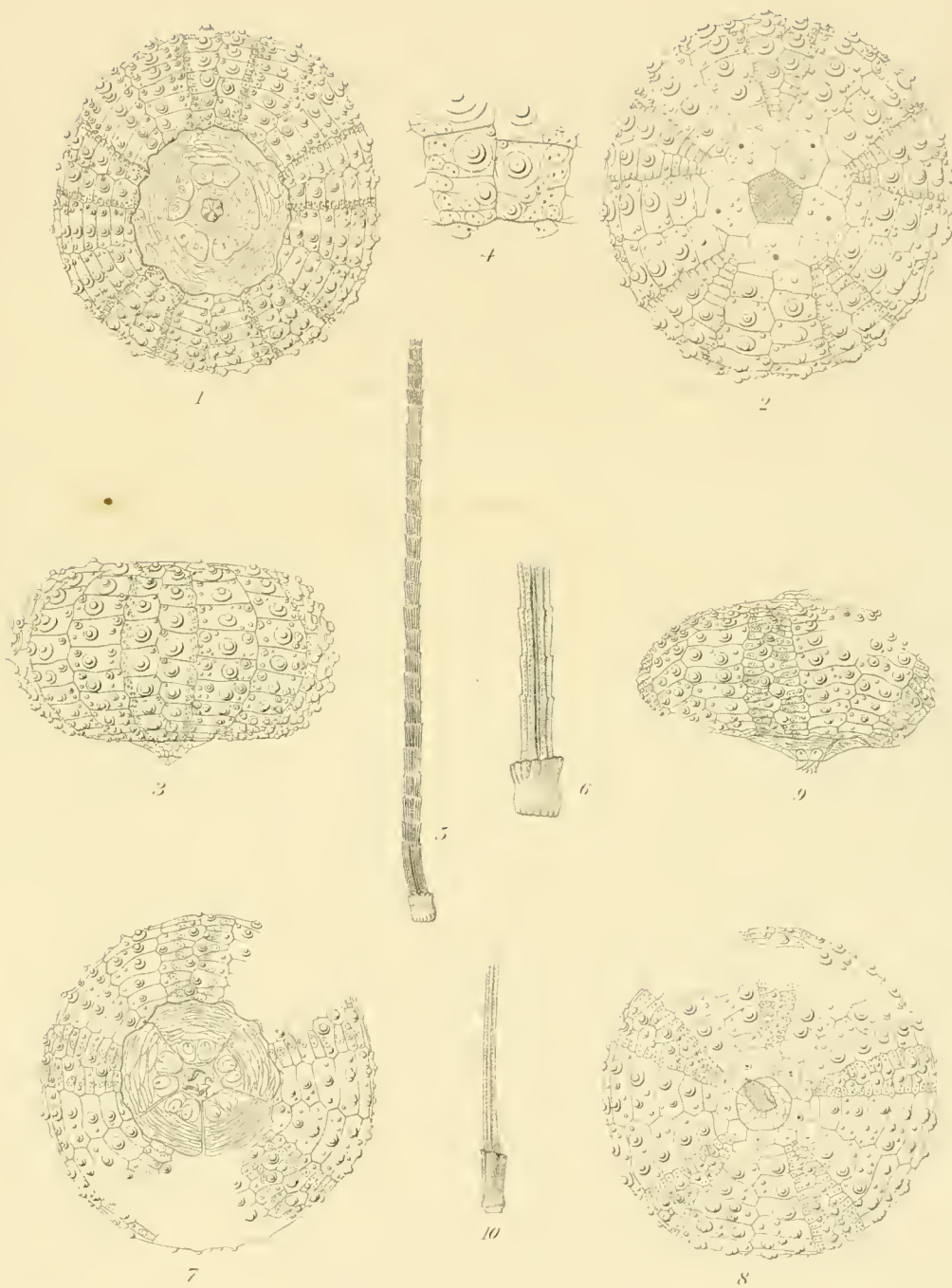
PLATE 55.

1-6. *Centrostephanus asteriscus* A. Ag. and Cl.

1. Actinal view of denuded test.  $\times 4$ .
2. Abactinal view of same.  $\times 4$ .
3. Side view of same, showing left anterior ambulacrum.  $\times 4$ .
4. Actinal portion of odd anterior ambulacrum.  $\times 10$ .
5. Basal half of primary spine.  $\times 5$ .
6. Base of same.  $\times 10$ .

7-10. *Leptodiadema purpureum* A. Ag. and Cl.

7. Actinal view of denuded test.  $\times 5$ .
8. Abactinal view of same.  $\times 5$ .
9. Side view of same, showing right anterior ambulacrum.  $\times 5$ .
10. Basal part of primary spine.  $\times 5$ .



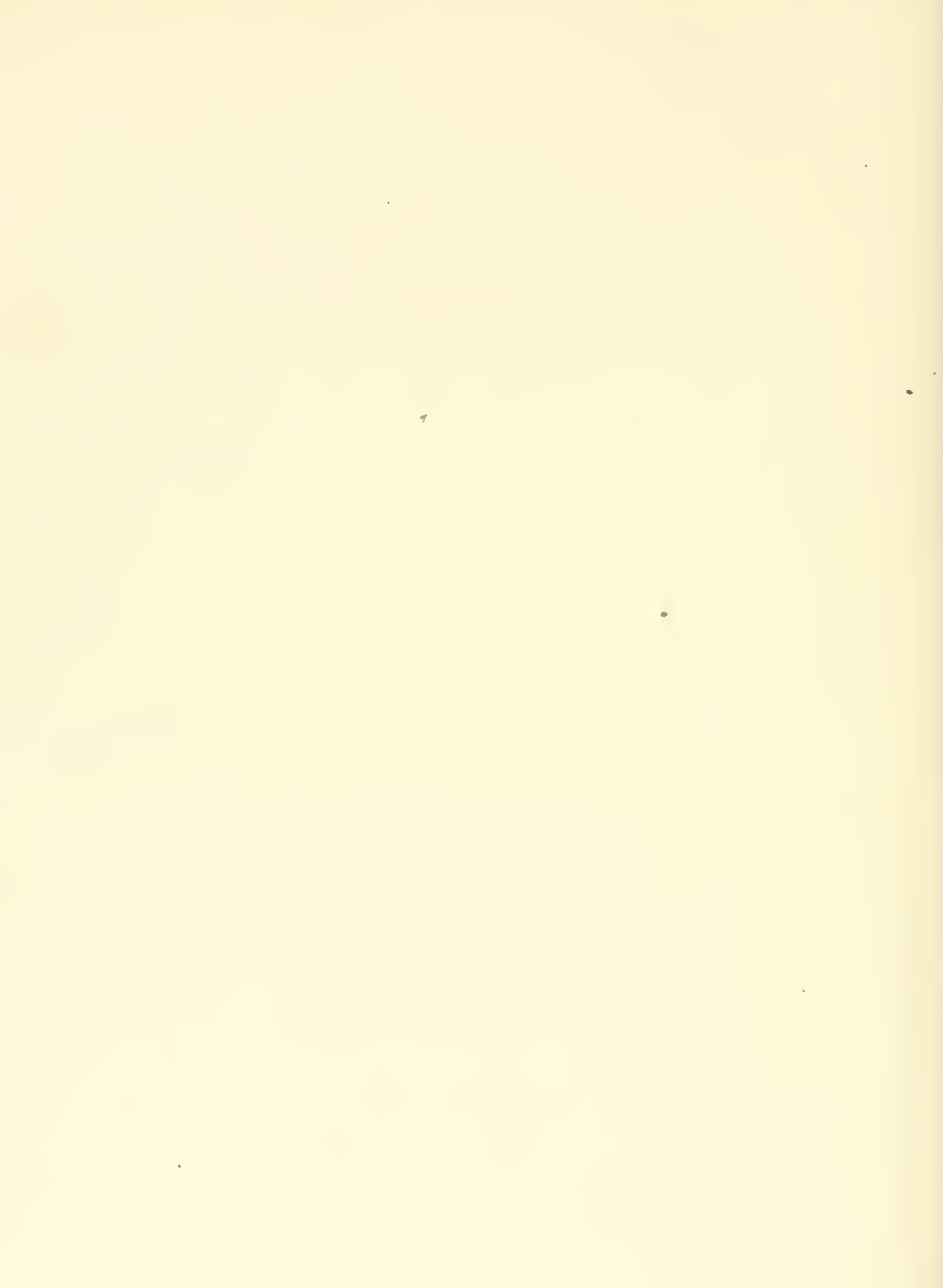


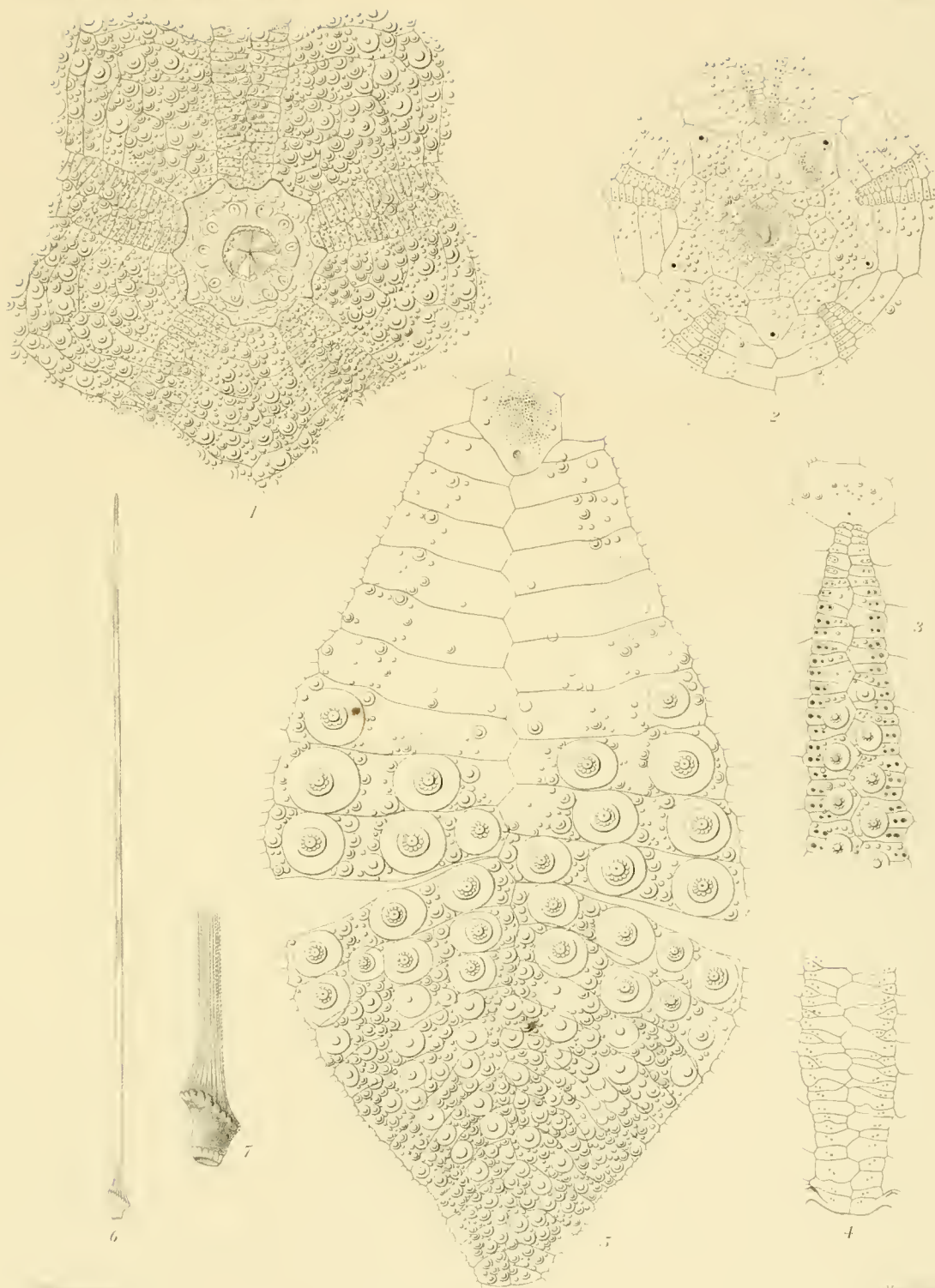


PLATE 56.

PLATE 56.

*Chætodiadema pallidum* A. Ag. and Cl.

1. Actinostome and adjoining part of denuded test.  $\times 2$ .
2. Abactinal system of same.  $\times 2$ .
3. Abactinal part of odd anterior ambulacrum seen from without.  $\times 3$ .
4. Actinal part of same ambulacrum seen from within.  $\times 3$ .
5. Right anterior interambulacrum, laid out flat.  $\times 3$ .
6. Primary spine.  $\times 2$ .
7. Base of same.  $\times 4$ .



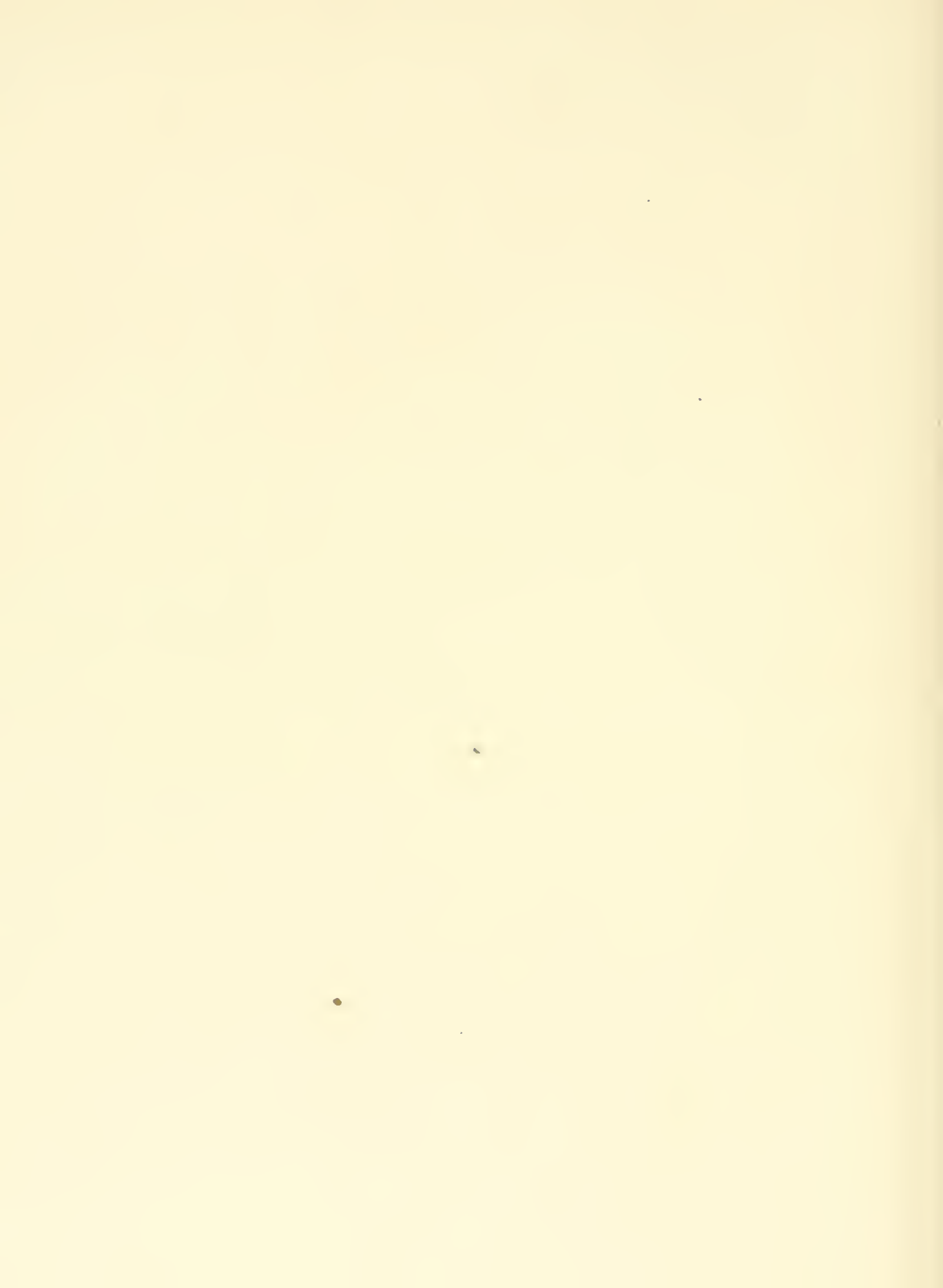


PLATE 57.

PLATE 57.

1-3. *Salenia cineta* A. Ag. and Cl.

1. Ambulacral view of a specimen somewhat inclined.
2. Actinal view of partly denuded specimen.
3. Abactinal view of same.

4-6. *Cœlopleurus maculatus* A. Ag. and Cl.

4. Actinal view of medium-sized specimen.
5. Abactinal view of same.
6. Side view of same.

All figures natural size.



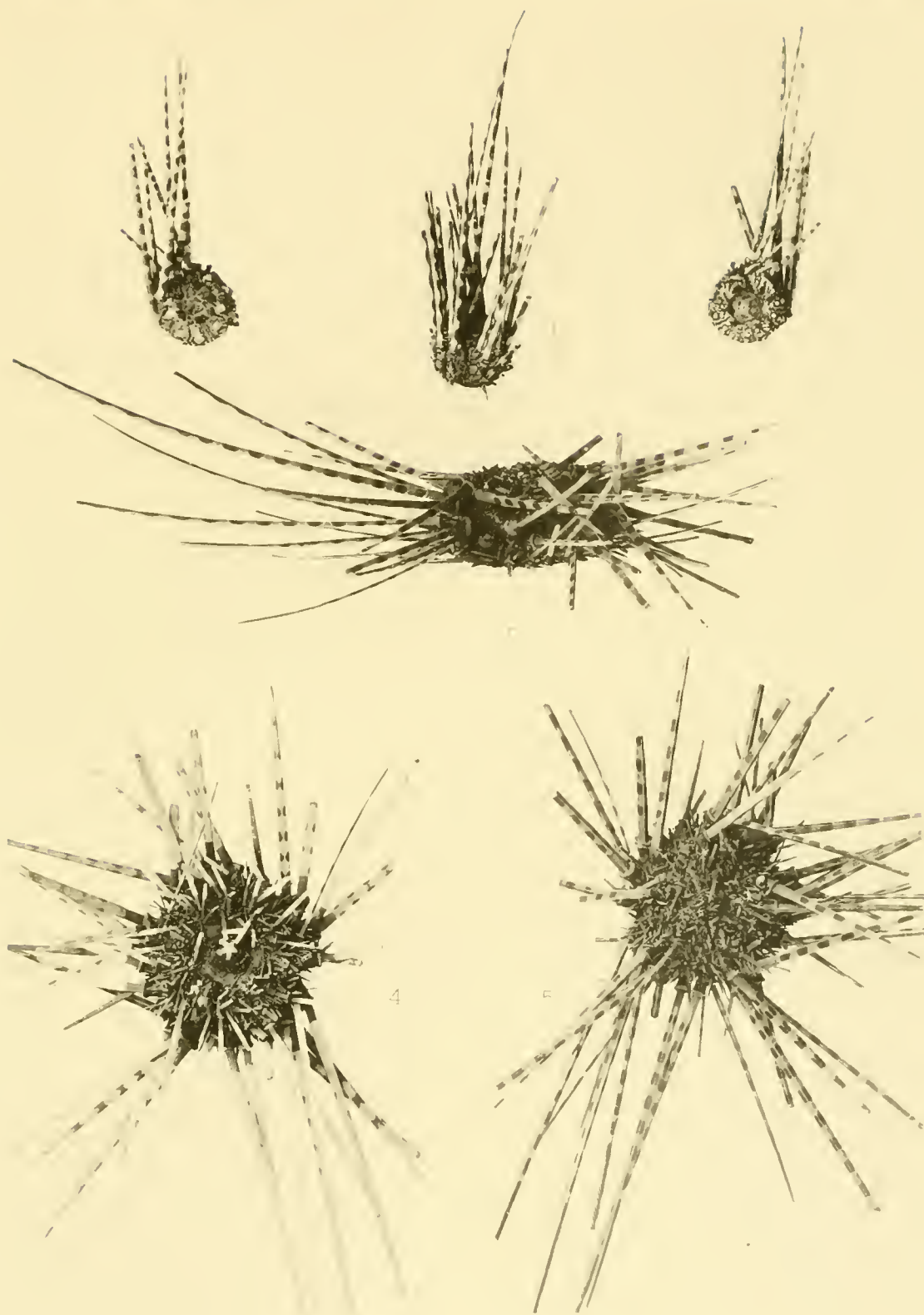




PLATE 58.

PLATE 58.

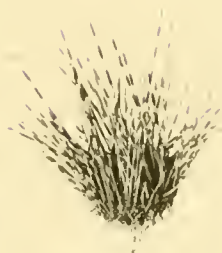
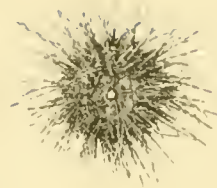
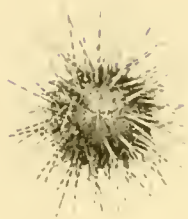
1-6. *Centrostephanus asteriscus* A. Ag. and Cl.

1. Side view.
2. Abactinal view, showing the white star.
3. Actinal view.
4. Abactinal view of denuded test.
5. Actinal view of same.
6. Ambulacral view of same.

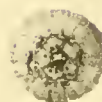
7-8. *Aspidodiadema meijerei* A. Ag. and Cl.

7. Abactinal view of a specimen from Station 3839, in which the abactinal system is hypertrophied by several parasitic gasteropods (Stylifer?).
8. Abactinal view of the same specimen, with abactinal system denuded to show the modification of the genital and ocular plates.

All figures natural size.



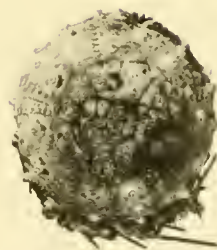
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PLATE 59.

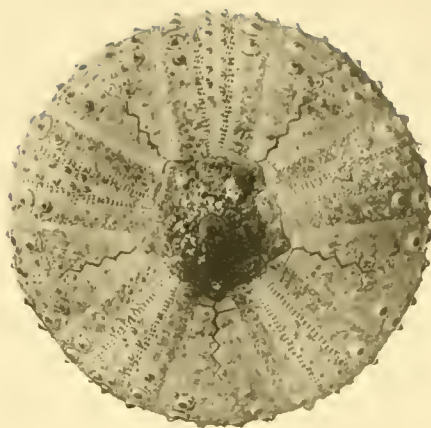
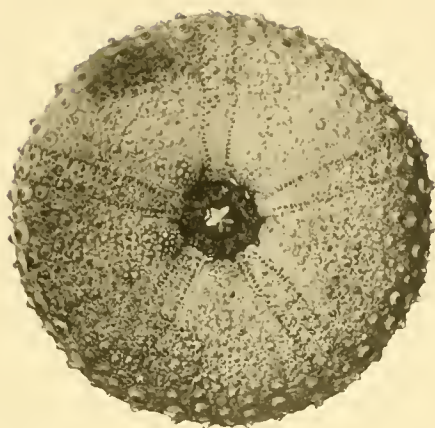
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PLATE 59.

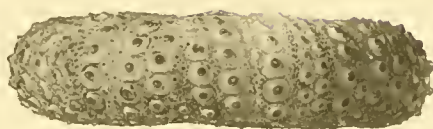
*Chætodiadema pallidum* A. Ag. and Cl.

1. Actinal view.
2. Abactinal view.
3. Actinal view of denuded specimen.
4. Abactinal view of same.
5. Side view of same.

All figures natural size.



4



5

